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**Eguchi**

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(54) **SEMICONDUCTOR DEVICE,  
ELECTRO-OPTICAL UNIT, AND  
ELECTRONIC APPARATUS**

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(30) **Foreign Application Priority Data**

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**H01L 29/40** (2006.01)  
**H01L 29/04** (2006.01)  
**H01L 29/15** (2006.01)

(52) **U.S. Cl.** ..... **257/776; 257/72; 257/758; 257/774; 257/734**

(58) **Field of Classification Search** ..... **257/72, 257/758, 774, 776, 781, 736, 790, 786, 731, 257/734**

See application file for complete search history.

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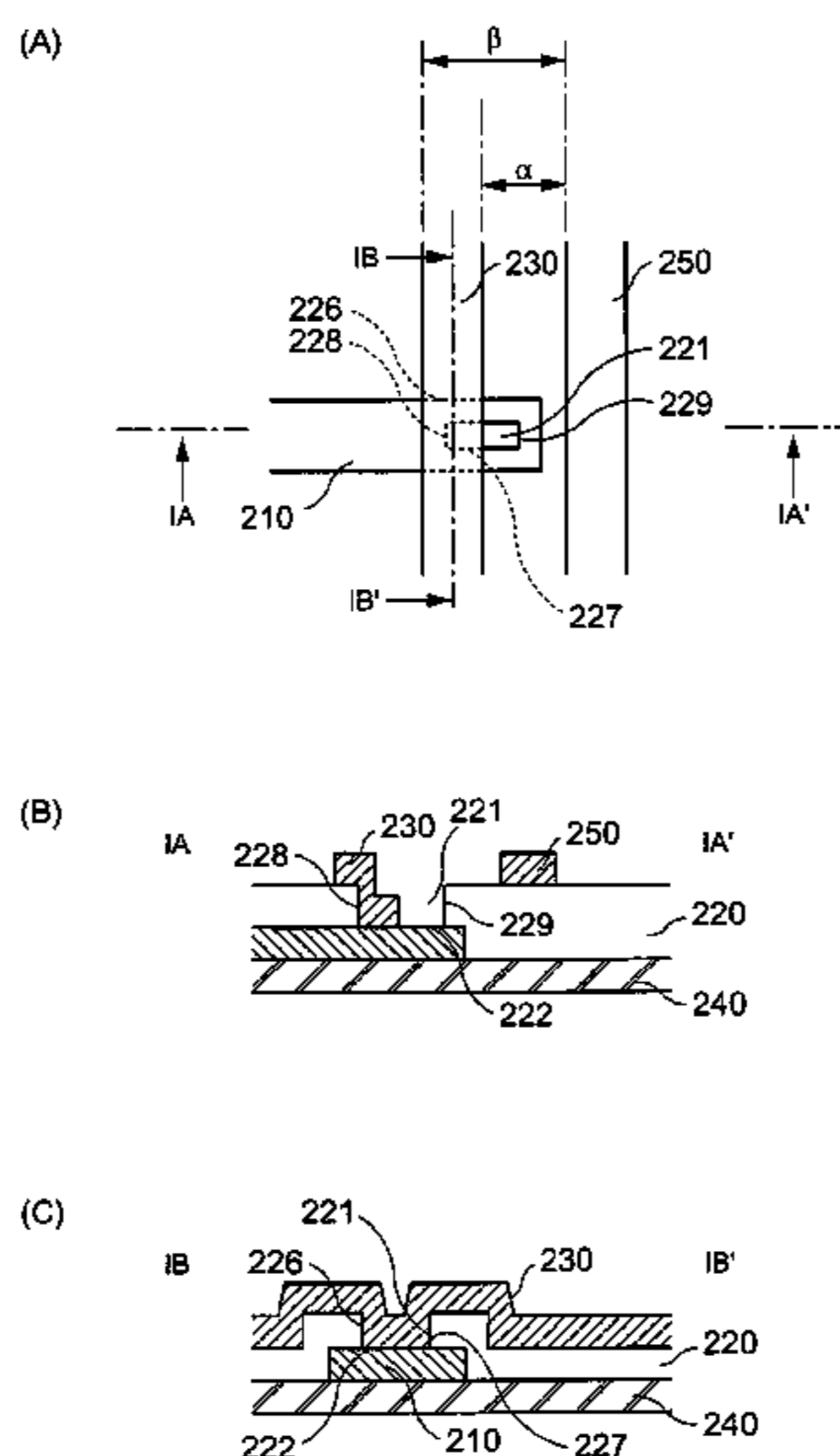
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(57) **ABSTRACT**

The invention provides a semiconductor device that allows high-scale integration of a pattern layout to reduce the pitch of wiring lines without changing a design rule, and to provide an electro-optical unit and an electronic apparatus including the semiconductor device. The semiconductor device can include a substrate, which has the following layers thereon: in order, a first conductive layer, an insulating interlayer having a contact hole therein at a position where it overlaps the first conductive layer in plan view, and a second conductive layer electrically connected to the first conductive layer via the contact hole. The first conductive layer entirely overlaps the contact hole, while the second conductive layer partially overlaps the contact hole in plan view. The first conductive layer is in contact with the second conductive layer at a part of a bottom area of the contact hole.

**10 Claims, 16 Drawing Sheets**



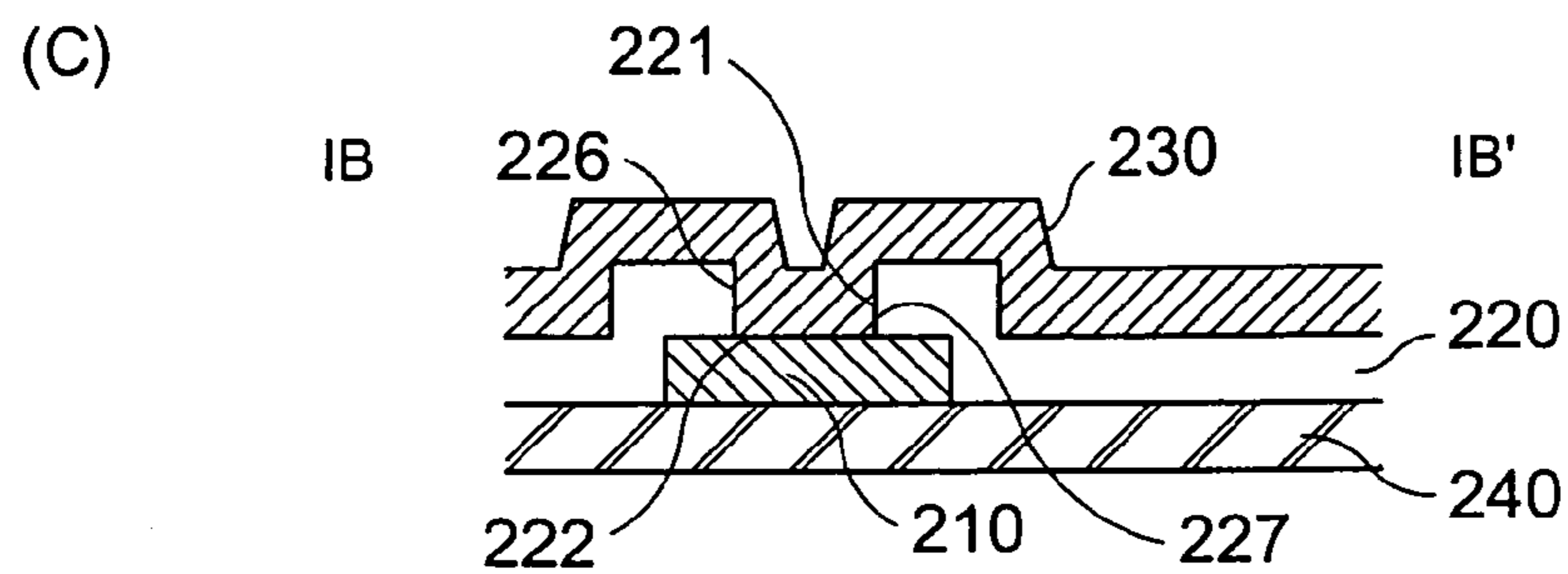
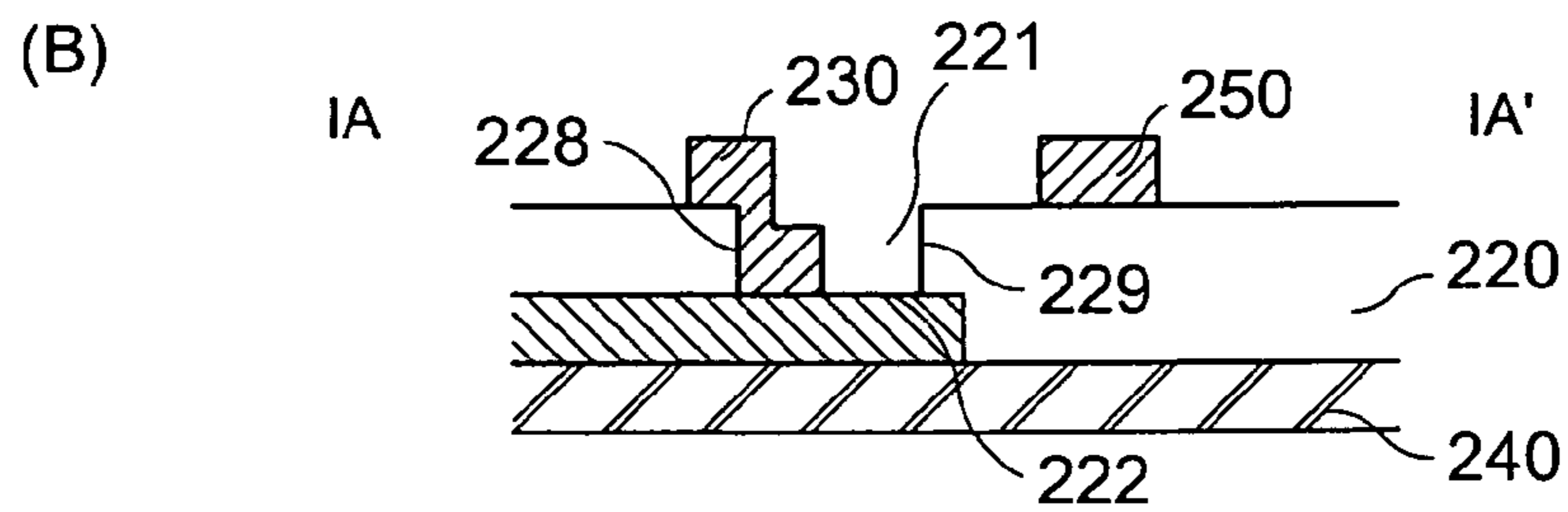
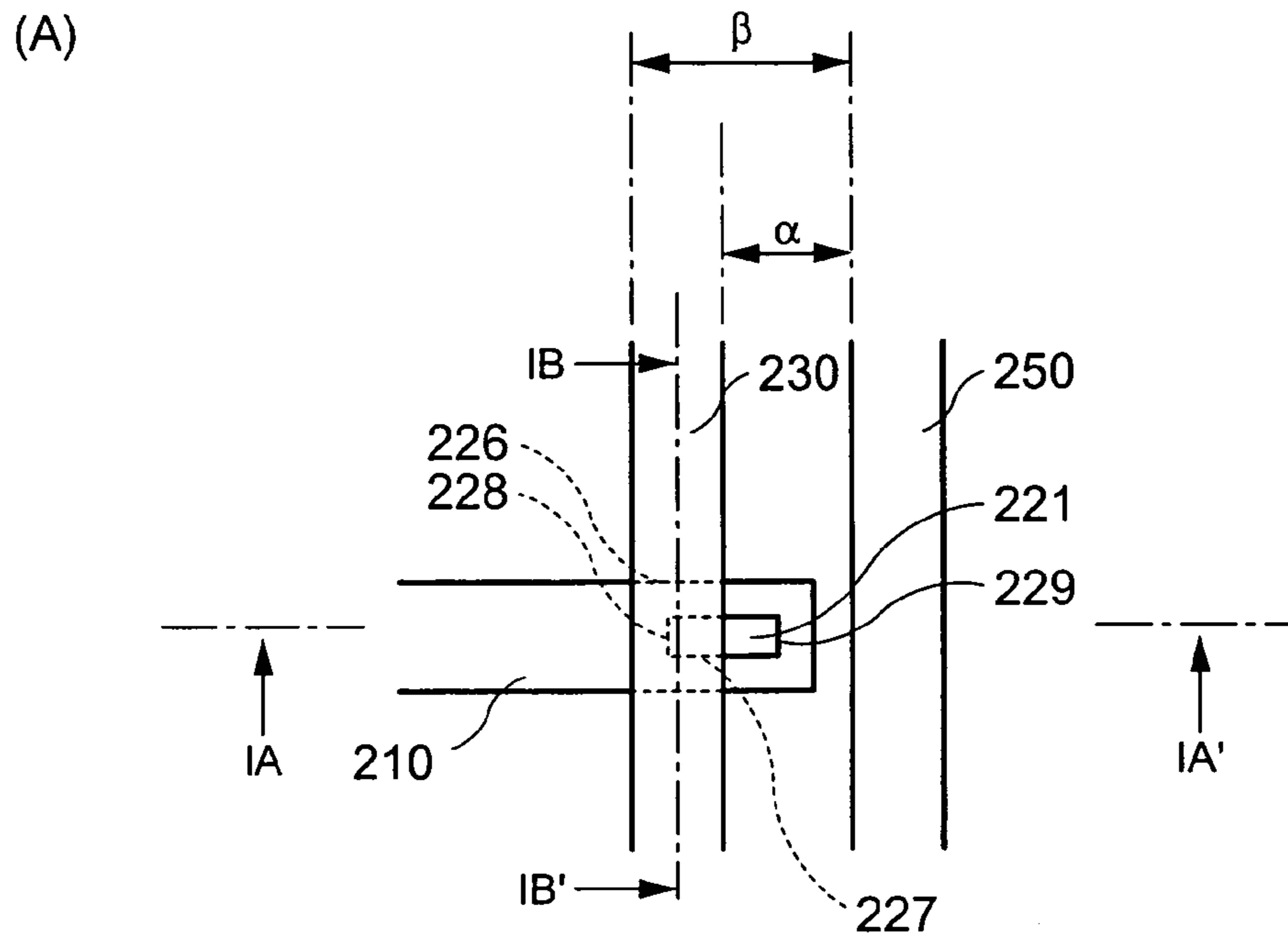


FIG. 1

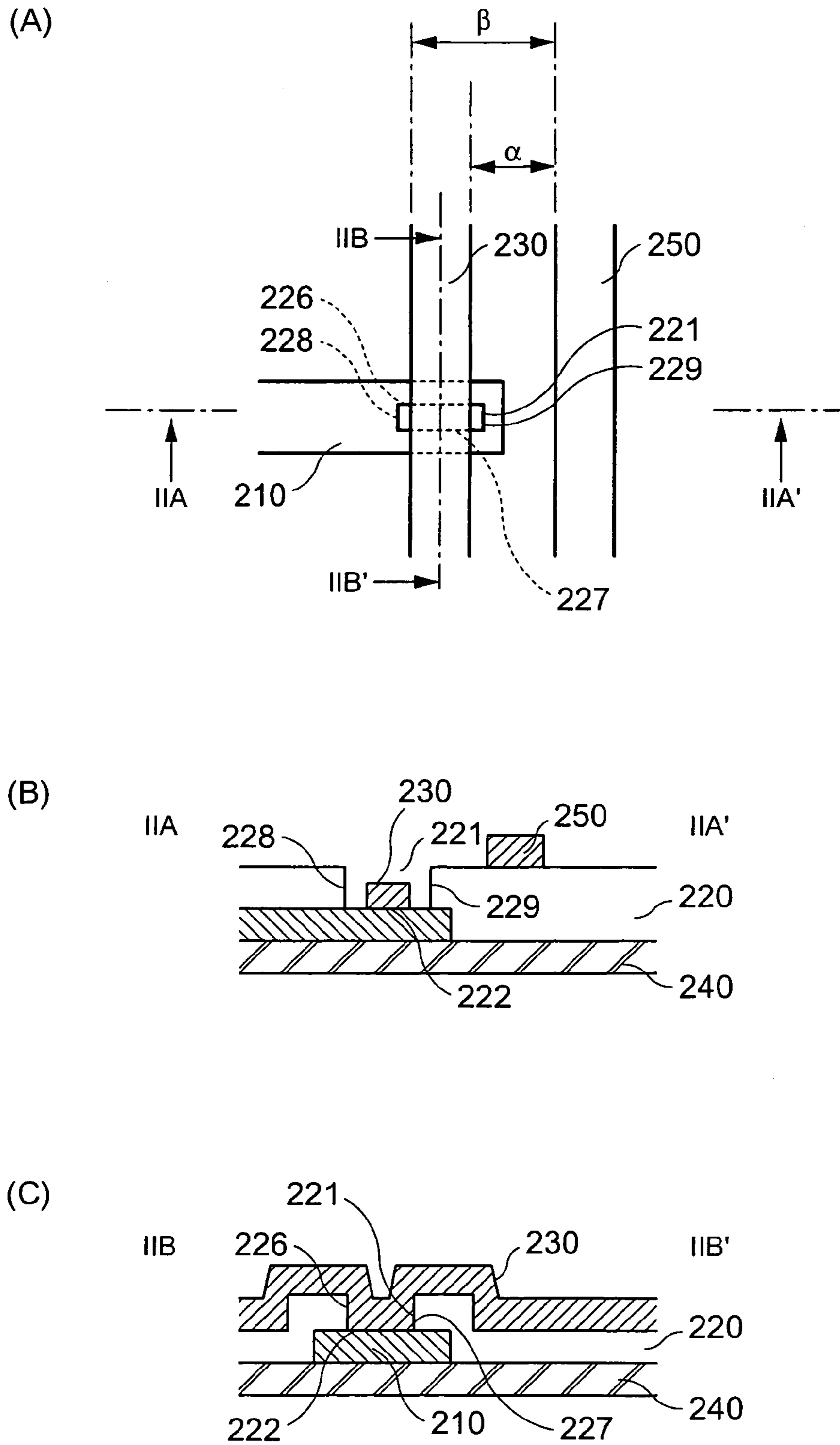


FIG. 2

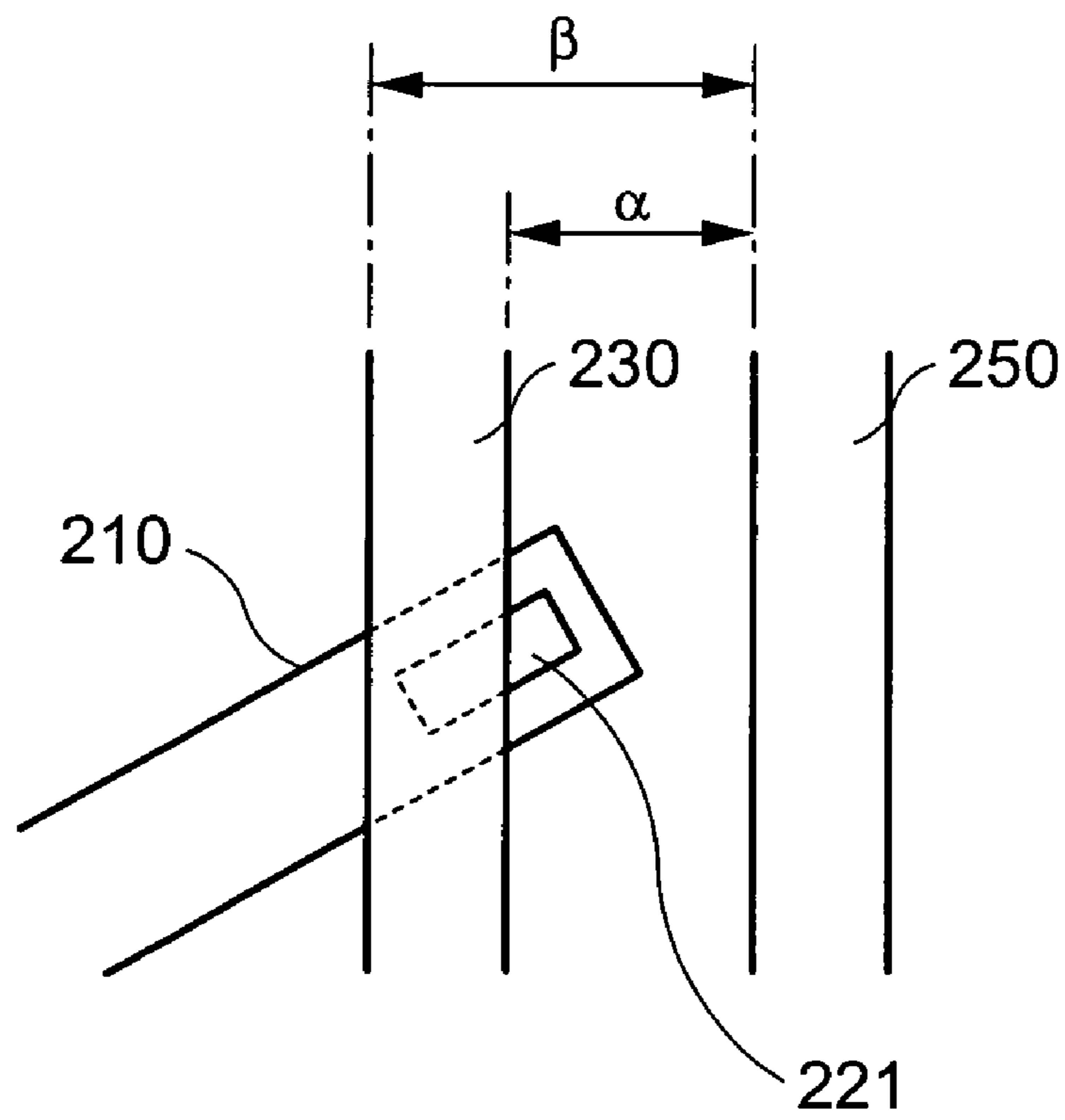


FIG. 3

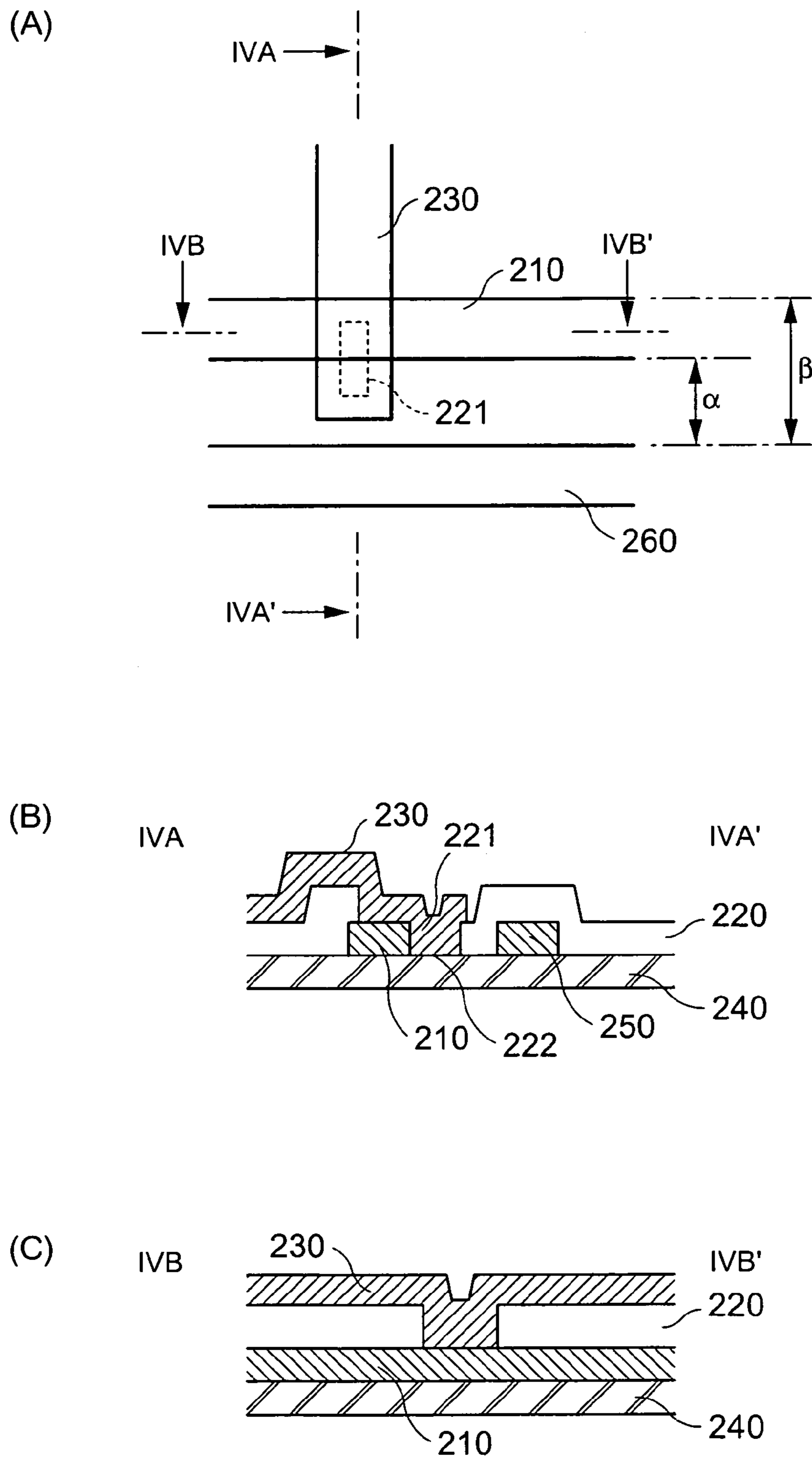
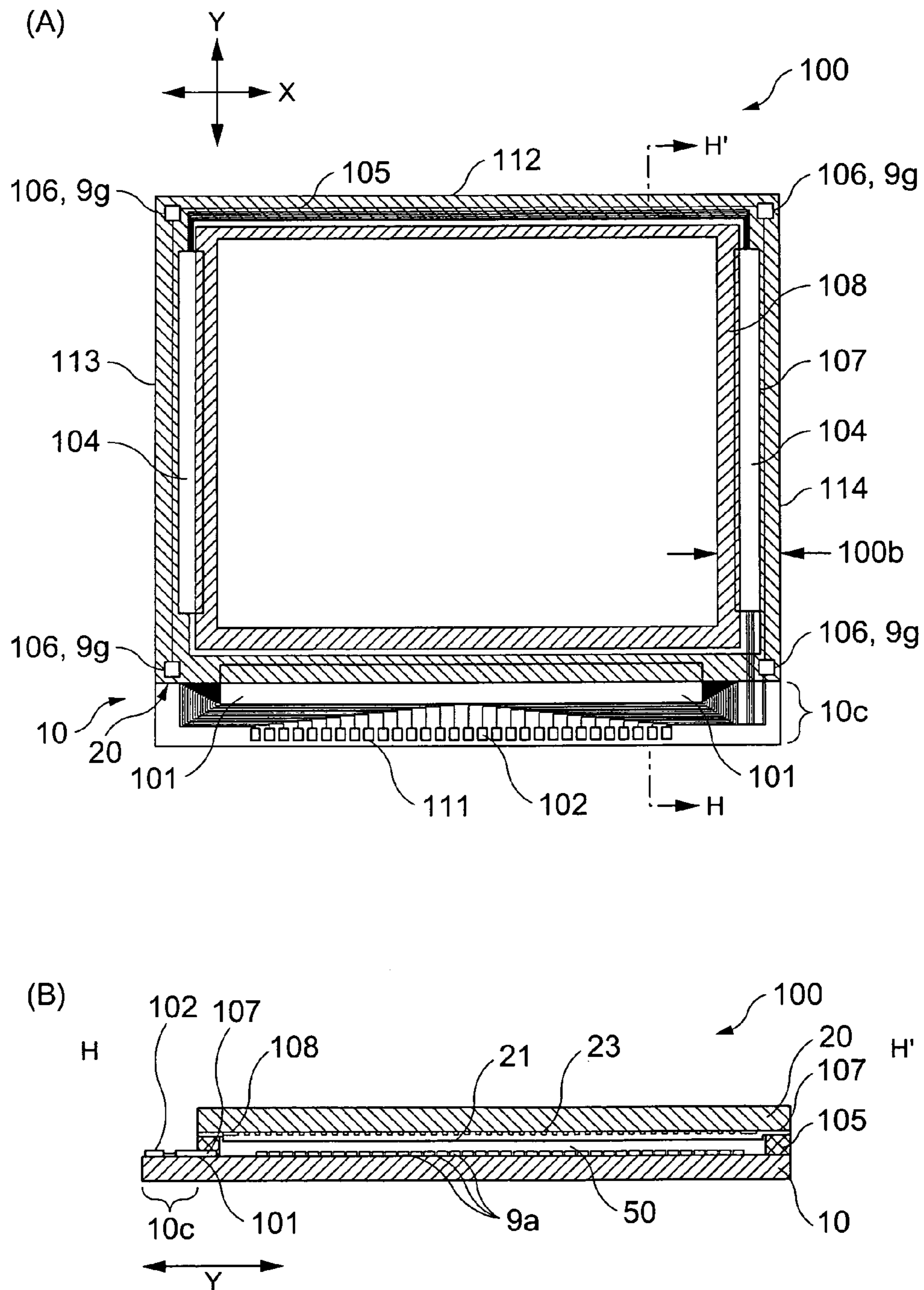


FIG. 4





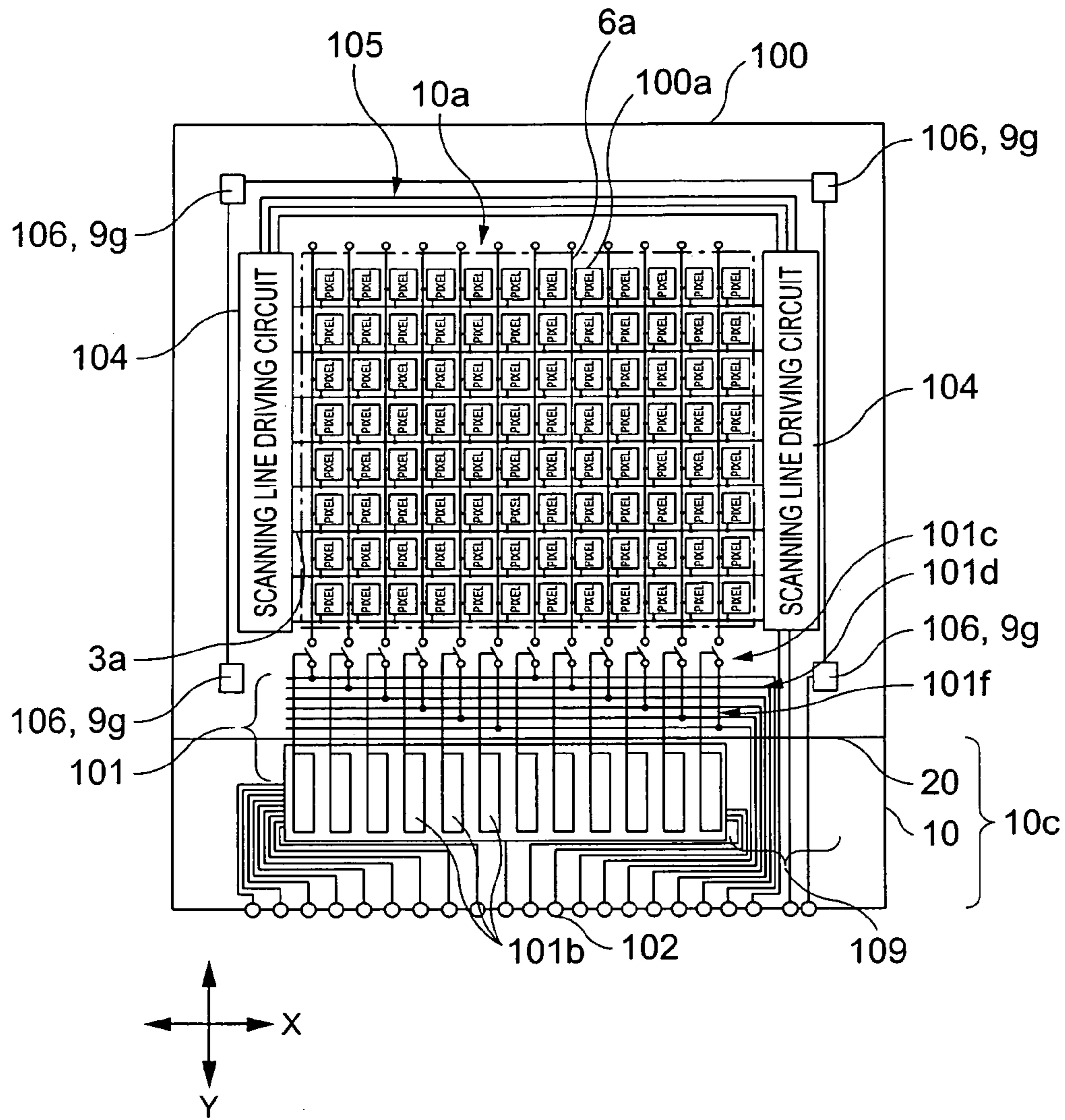


FIG. 6

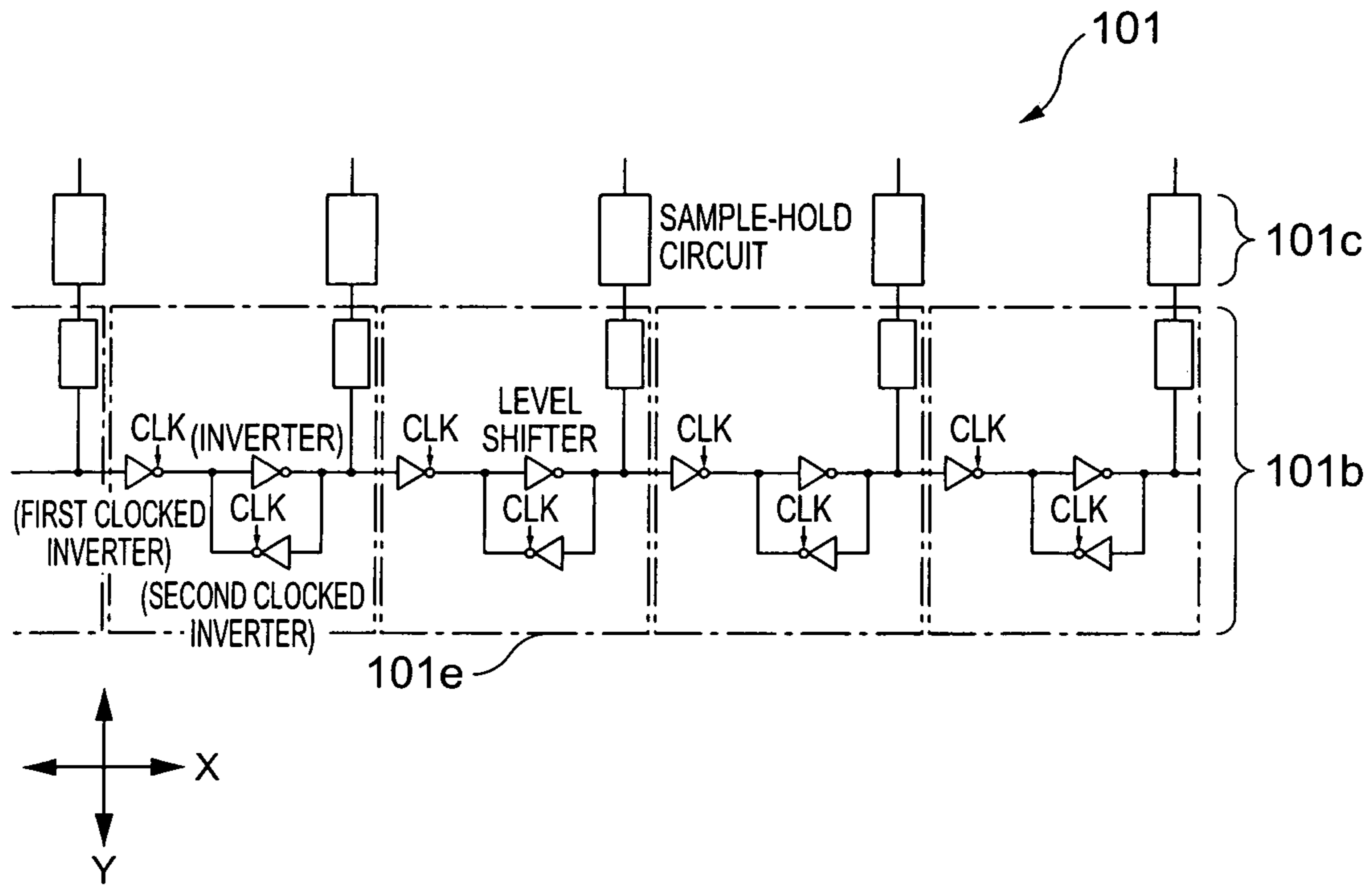


FIG. 7



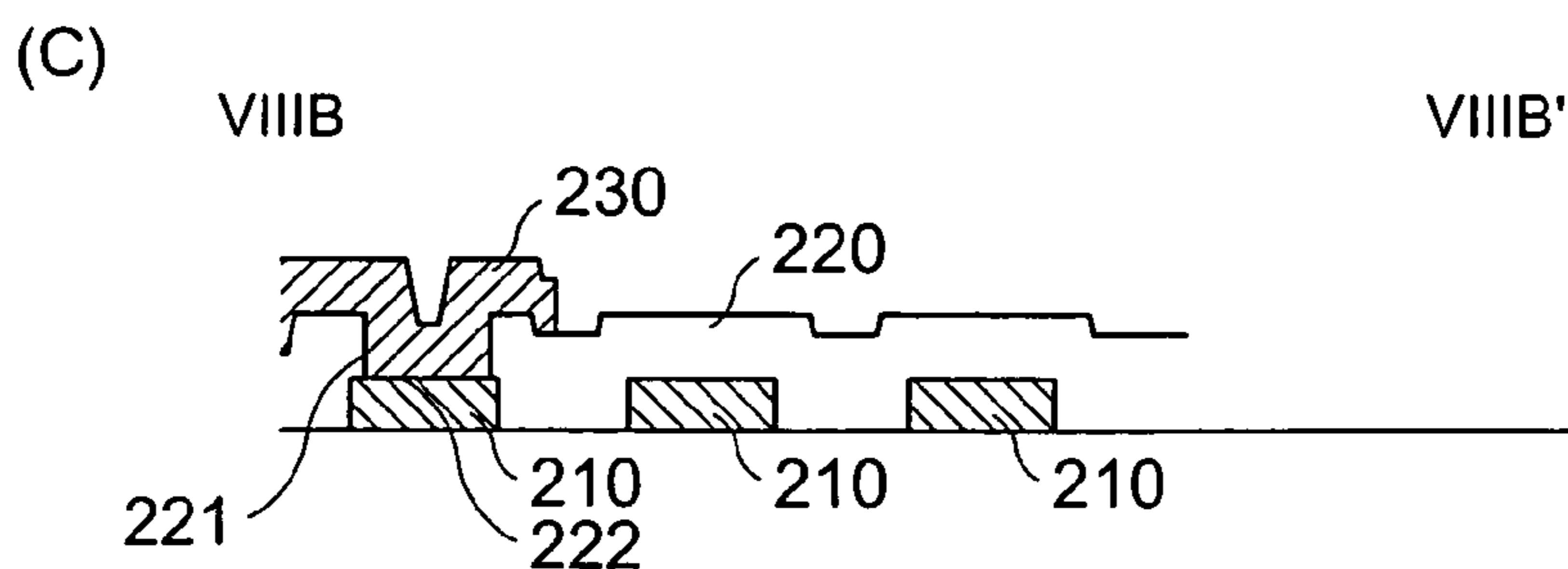
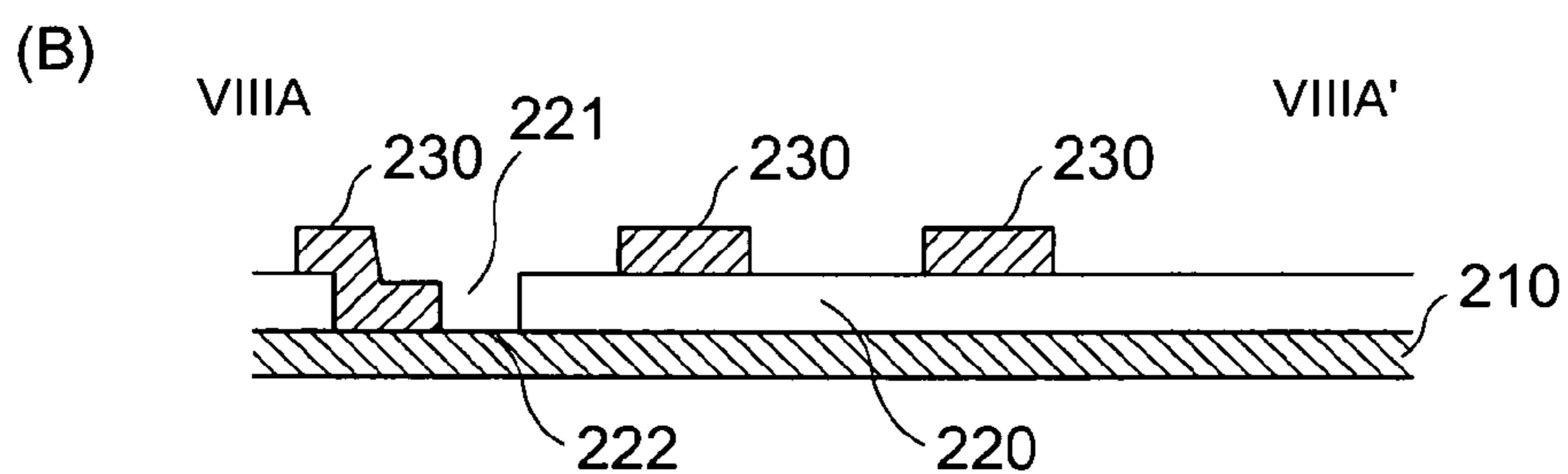
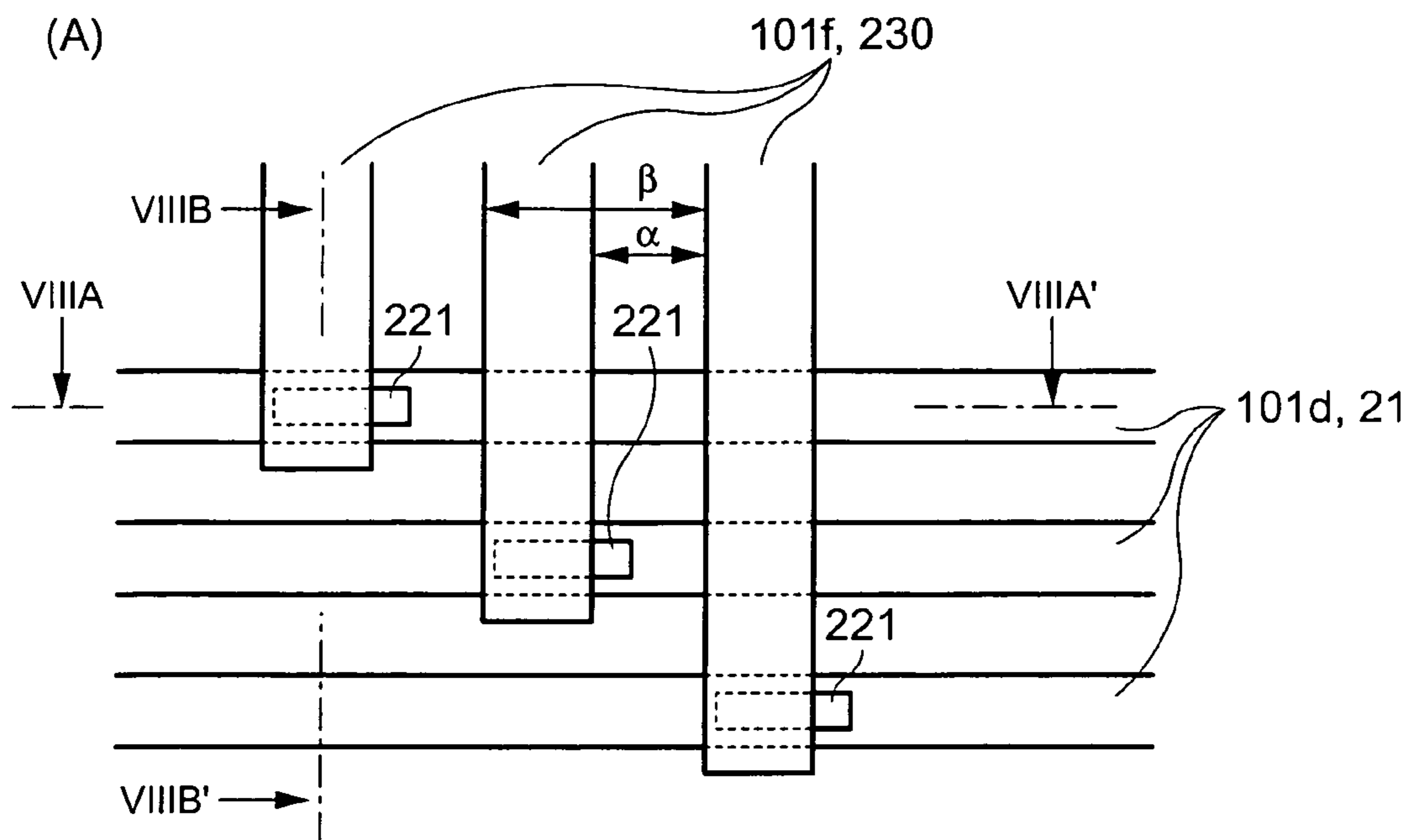


FIG. 8

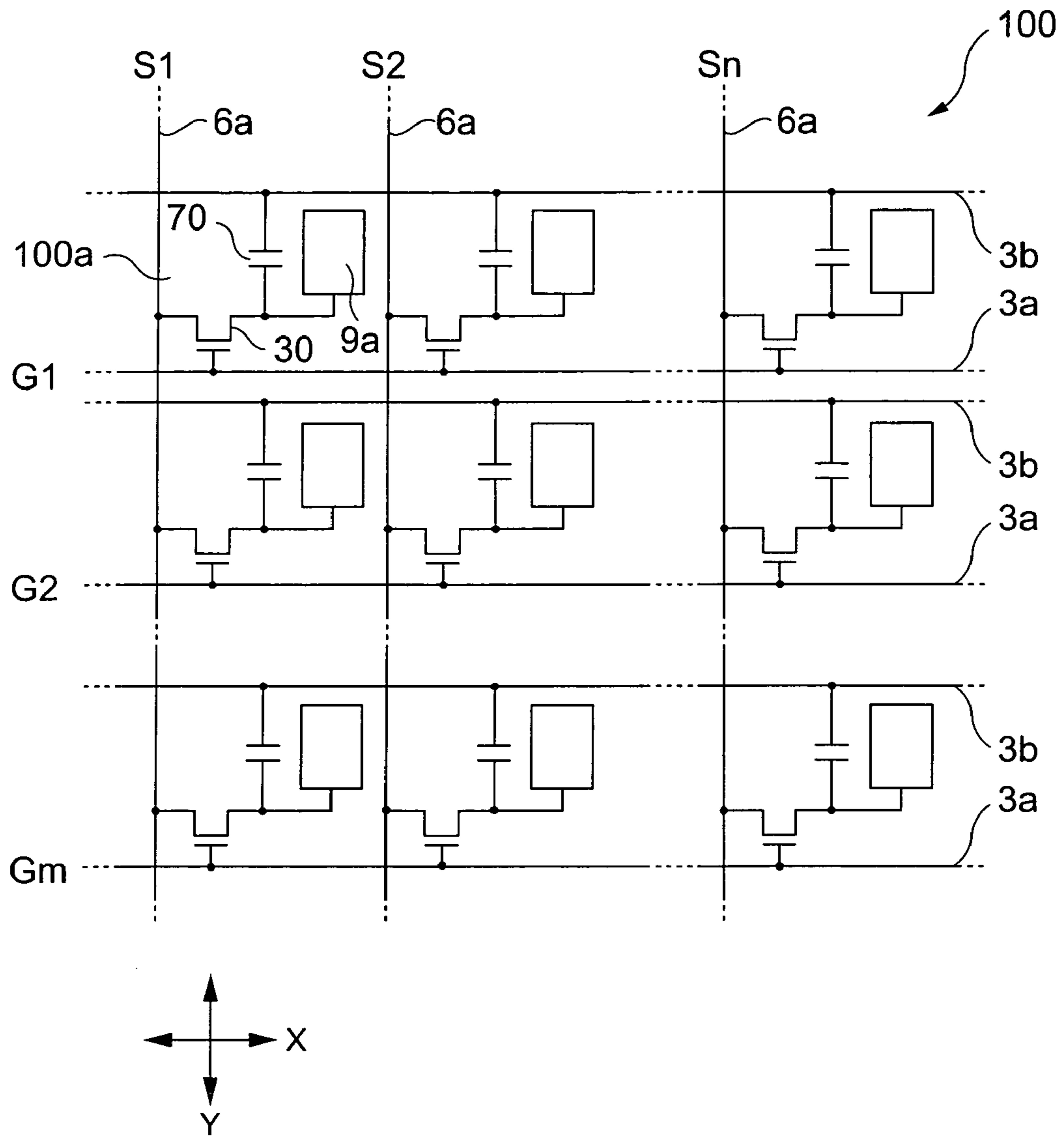


FIG. 9

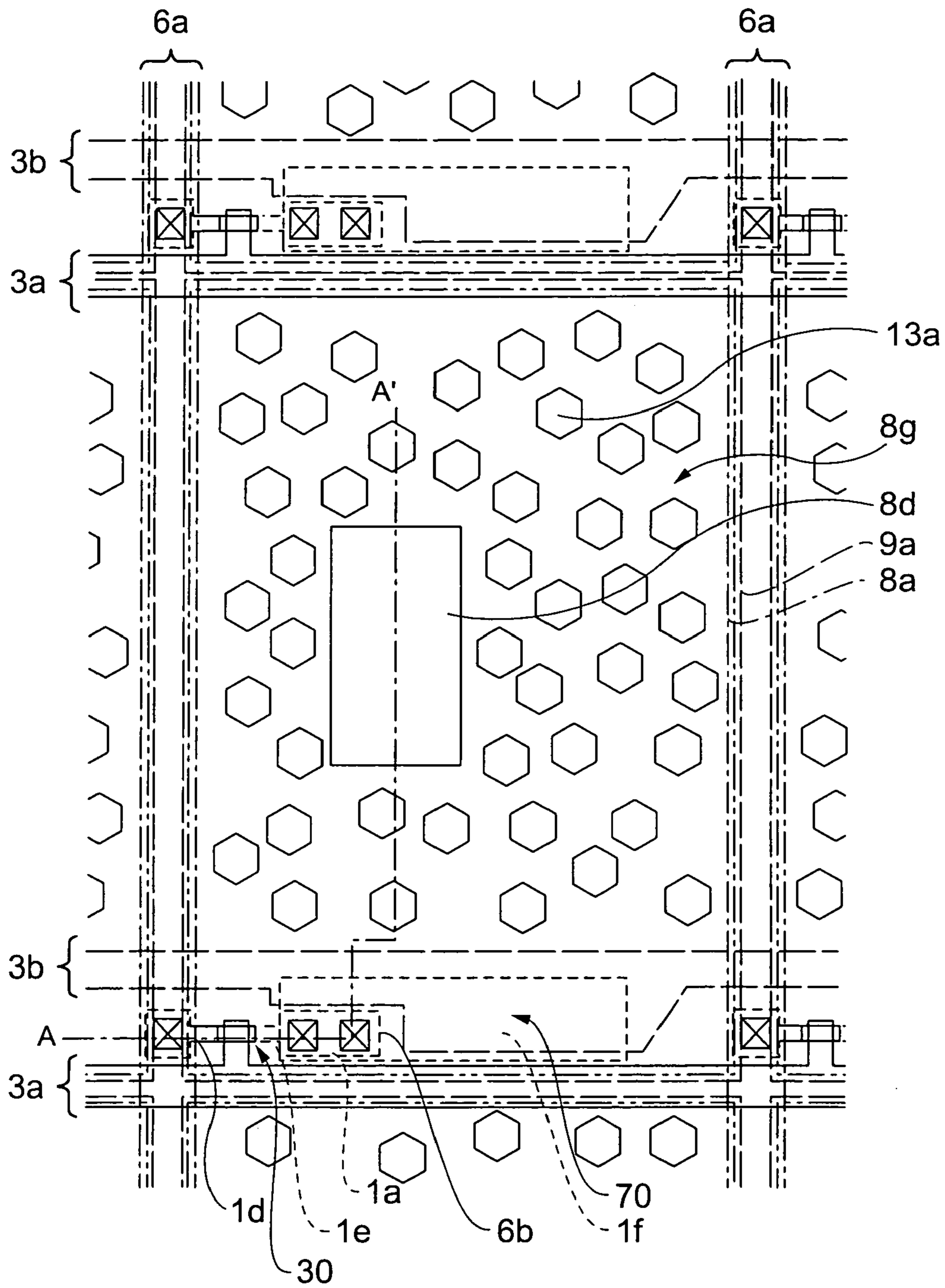


FIG. 10

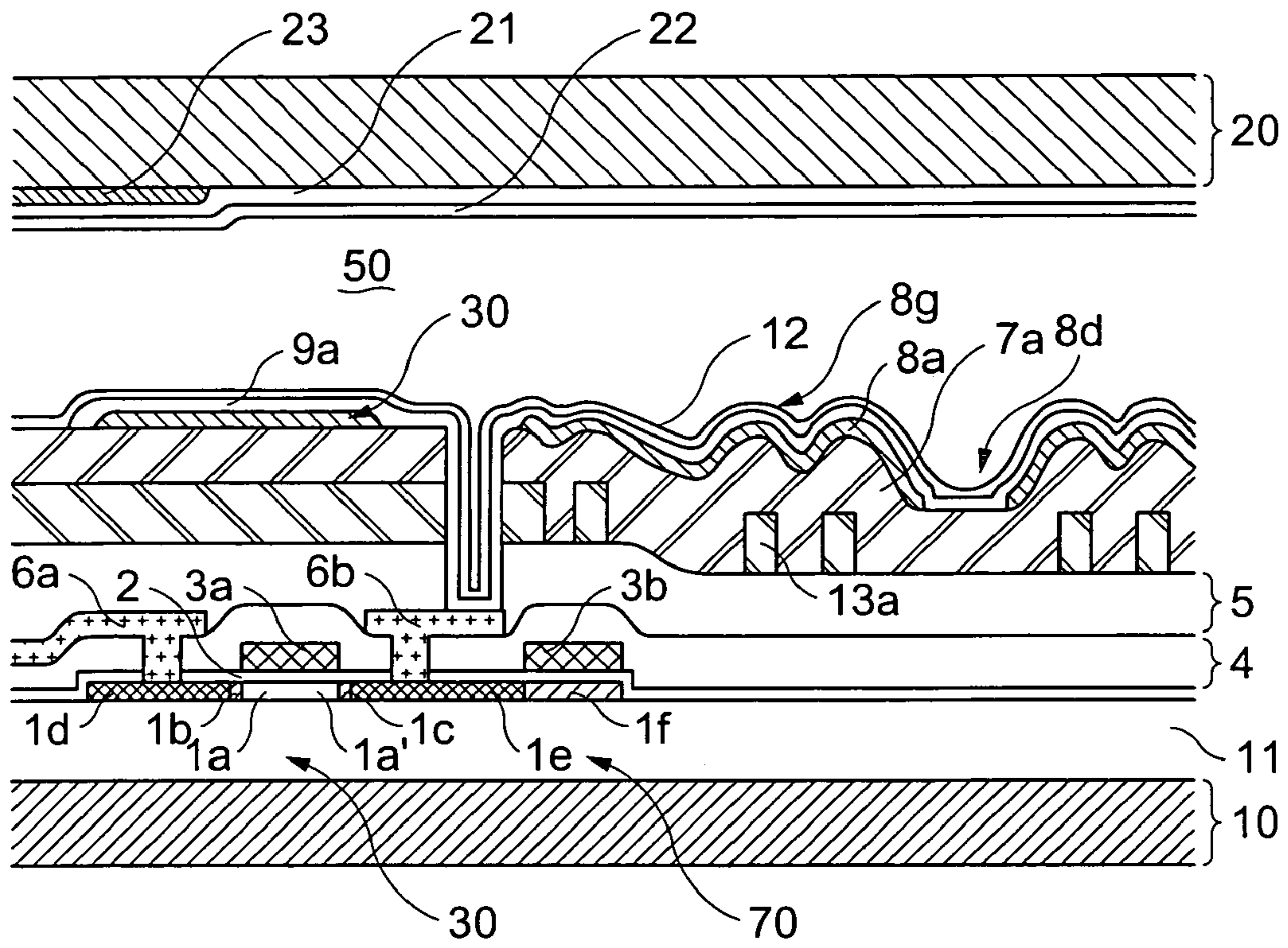


FIG. 11

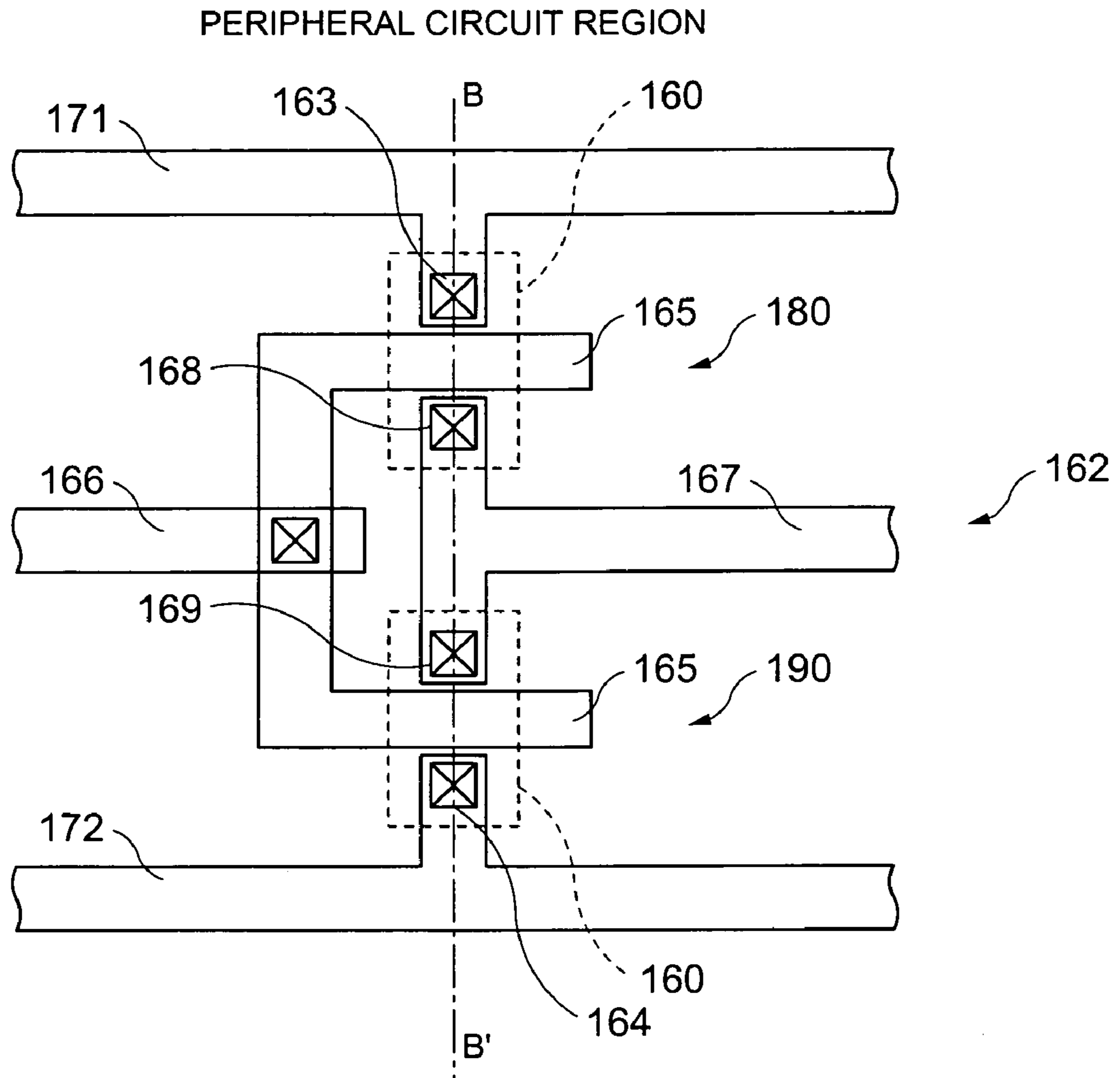


FIG. 12



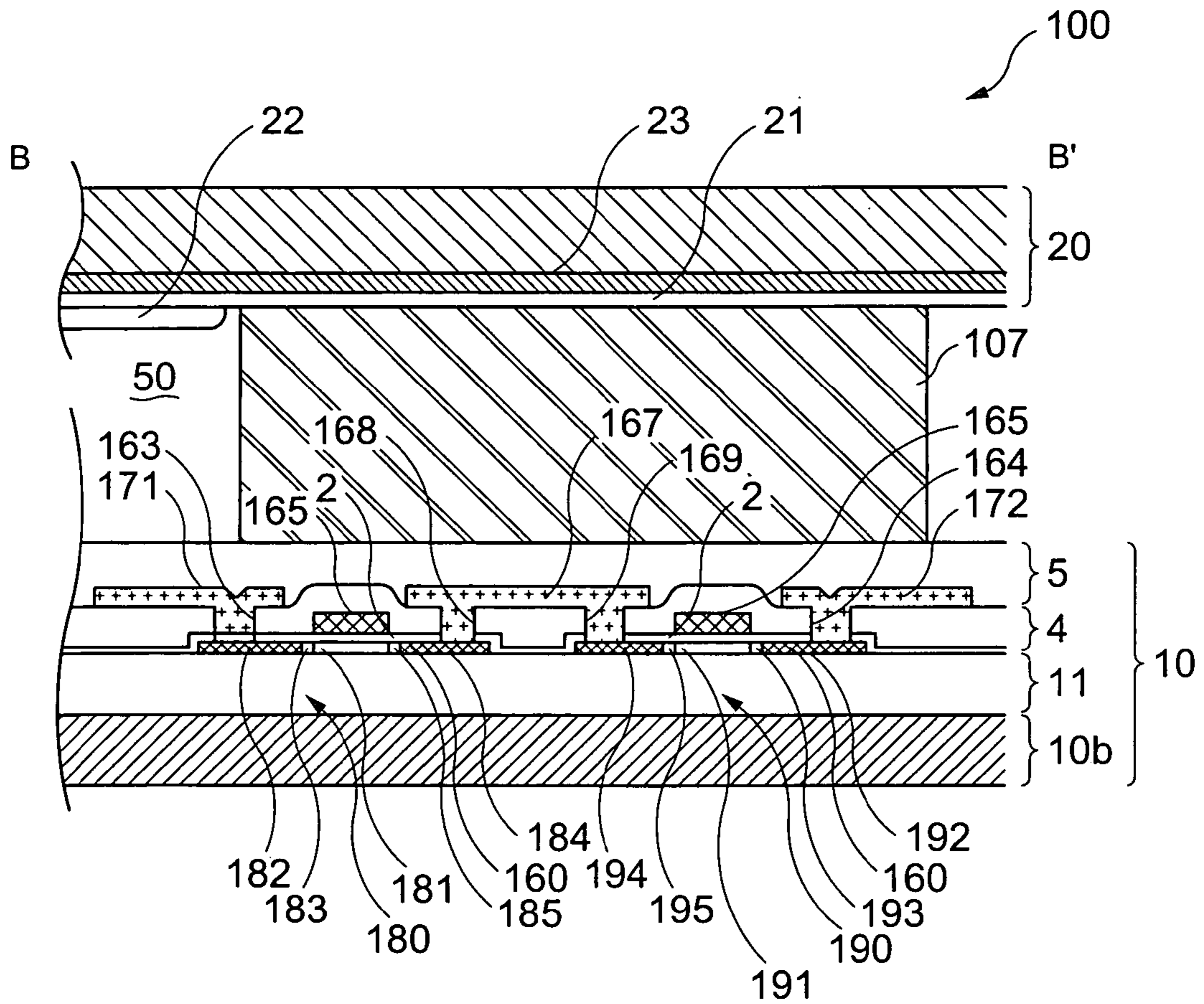


FIG. 13



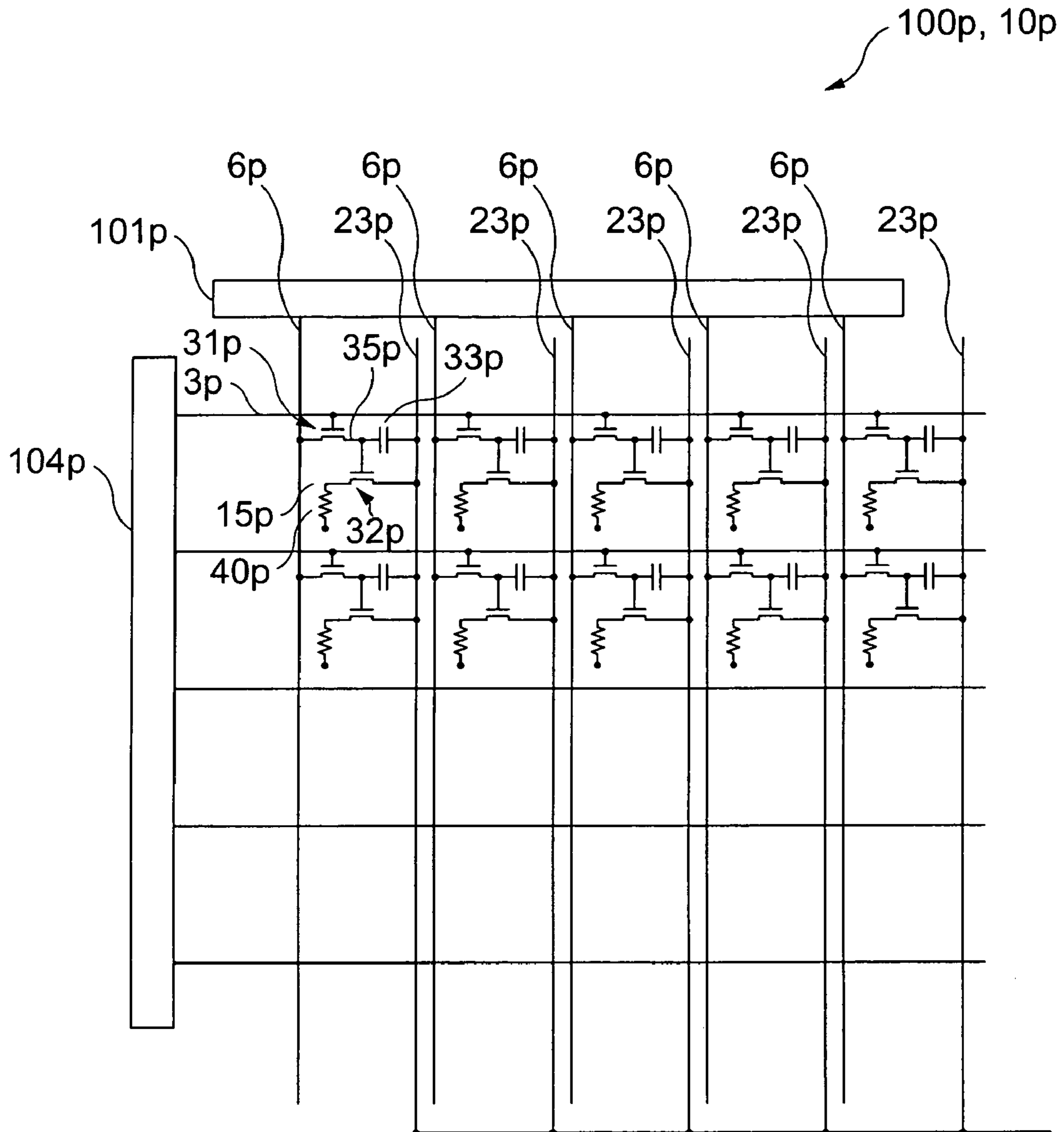


FIG. 14

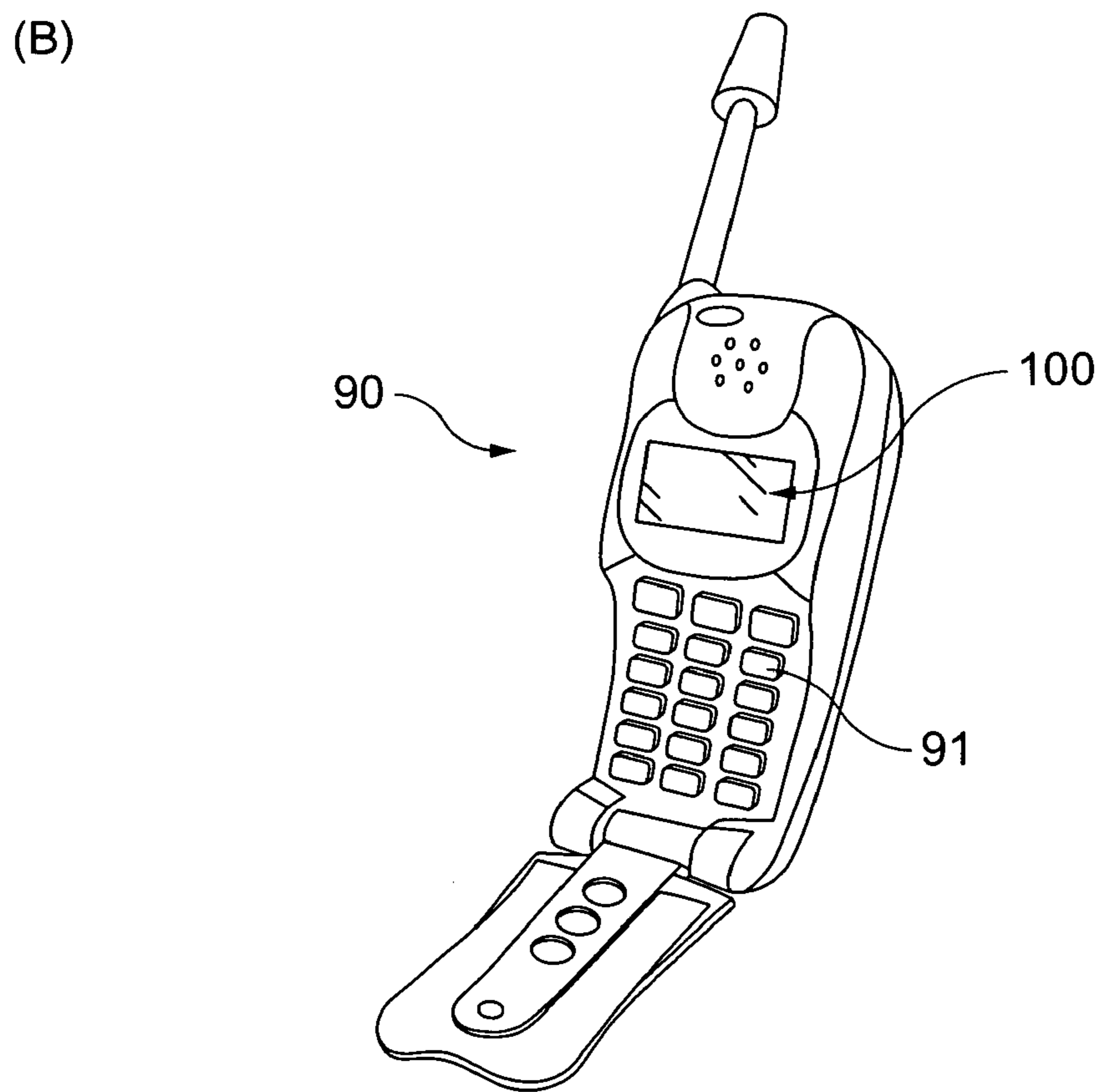
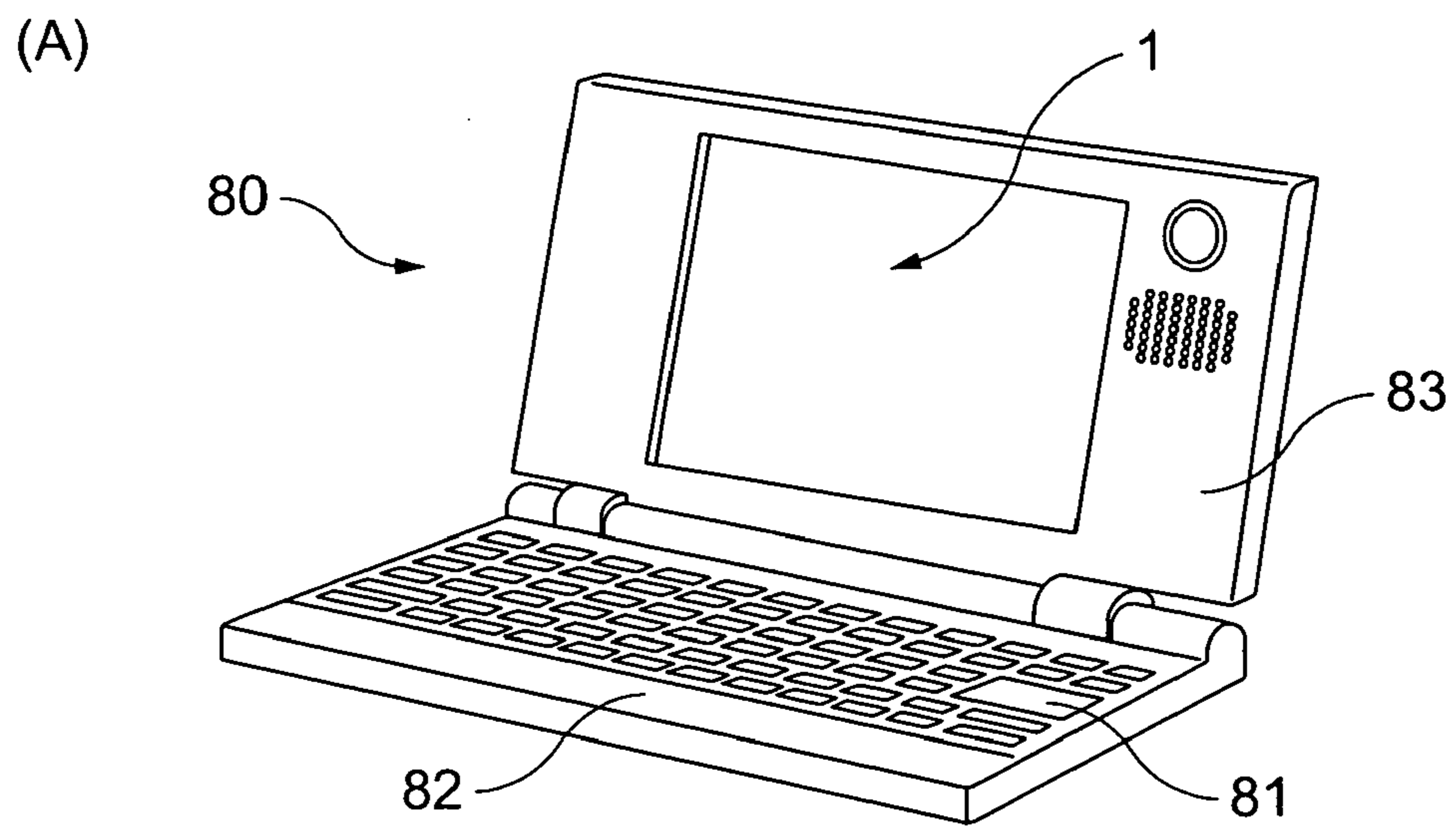


FIG. 15

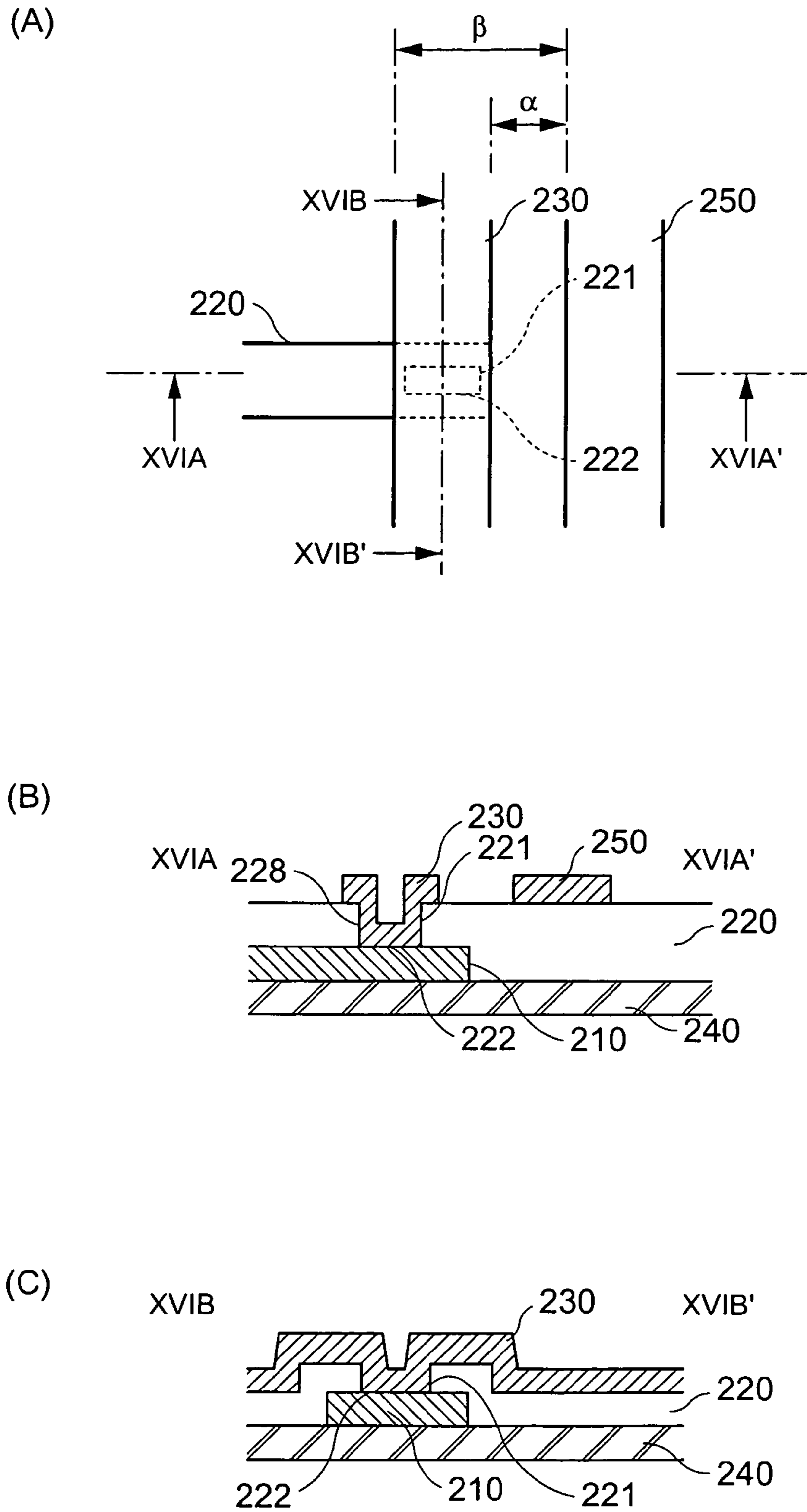


FIG. 16



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**SEMICONDUCTOR DEVICE,  
ELECTRO-OPTICAL UNIT, AND  
ELECTRONIC APPARATUS**

BACKGROUND OF THE INVENTION

1. Field of Invention

The present invention relates to a semiconductor device in which contact holes in an insulating interlayer are used for electrical connections, and to an electro-optical unit and an electronic apparatus including the semiconductor device.

2. Description of Related Art

Recently, electro-optical devices including liquid crystal devices and electroluminescent (EL) display panels have become popular as display units of electronic apparatuses, such as mobile telephones, mobile computers, and video cameras. Such electro-optical devices have a plurality of elements including transistors and diodes mounted on a substrate to form predetermined circuits, and also have a plurality of wiring lines to electrically connect these elements.

In such wiring lines, lower and upper conductive layers having an insulating interlayer therebetween are electrically connected via a contact hole in the insulating interlayer. That is, with reference to FIGS. 16(A), 16(B), and 16(C), a substrate 240 has the following layers thereon: in order, a first conductive layer 210, an insulating interlayer 220 having a contact hole 221 therein at the position where it overlaps the first conductive layer 210 in plan view, and a second conductive layer 230 electrically connected to the first conductive layer 210 via the contact hole 221. In a known structure, both the first conductive layer 210 and the second conductive layer 230 overlap the entire contact hole 221 in plan view. Thus, the first conductive layer 210 is in contact with the second conductive layer 230 at the entire bottom area 222 of the contact hole 221. Herein, the second conductive layers 230 are, for example, a plurality of parallel wiring lines, and second conductive layers 250, which are also wiring lines, extend adjacent to the second conductive layers 230 in the same layer.

SUMMARY OF THE INVENTION

These wiring lines are formed by photolithography. The distance  $\alpha$  between the adjacent wiring lines in the same layer, namely, the second conductive layer 230 and the second conductive layer 250 in an upper layer, is determined by a design rule defined by the photolithography technology and photolithography machine used. In a known technology, the width of the upper conductive layer 230, which is a wiring line, must be greater than the length of the contact hole 221. Consequently, a pitch  $\beta$  of the wiring lines, namely, the second conductive layer 230 and the second conductive layer 250 in the upper layer, cannot be reduced, which is a problem. As a result, although an increase of the number of pixels in an electro-optical unit requires a reduction of the pitch  $\beta$  of the wiring lines, this cannot be realized, which is a problem.

Accordingly, an object of the present invention is to provide a semiconductor device that allows high-scale integration of a pattern layout to reduce the pitch of wiring lines without changing the design rule, and to provide an electro-optical unit and an electronic apparatus including such a semiconductor device.

A semiconductor device according to the invention can include a first conductive layer formed on a substrate, an insulating interlayer over the first conductive layer, the

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insulating interlayer having a contact hole being at least partially disposed directly on the first conductive layer, and a second conductive layer formed on the insulating interlayer, the second conductive layer being electrically coupled to the first conductive layer through the contact hole. In addition, the contact hole extends beyond either an edge of the first conductive layer or an edge of the second conductive layer in plan view.

In the semiconductor device according to the invention, since the contact hole extends beyond either an edge of the first conductive layer or an edge of the second conductive layer in plan view, the width of the second conductive layer (or the first conductive layer) can be reduced to be smaller than the length of the contact hole. Accordingly, a pitch of the second conductive layers (or the first conductive layers) can be reduced although a design rule distance between the second conductive layers (or the first conductive layers) cannot be reduced.

In the semiconductor device according to the invention, one of the first conductive layer and the second conductive layer may entirely overlap the contact hole and the other conductive layer may partly overlap the contact hole in plan view. Herein, for example, the one of the conductive layers is the first conductive layer and the other conductive layer is the second conductive layer.

According to the invention, a plurality of said other conductive layers extends parallel to one another at a predetermined pitch. In addition, the one of the conductive layers intersects the other conductive layer.

According to the invention, the other conductive layer may overlap the contact hole that is shifted to one side of the other conductive layer. Alternatively, the other conductive layer may overlap the contact hole such that two opposing edges of the contact hole are outside of said other conductive layer.

Preferably, in the case where the contact hole is rectangular, the other conductive layer partially overlaps the contact hole in its lengthwise direction. In the case where the contact hole is rectangular, the other conductive layer may extend diagonally with respect to the edges of the contact hole. For example, the semiconductor device according to the invention is used for a substrate of an electro-optical unit to hold an electro-optical substance and pixels having pixel switching transistors and pixel electrodes are disposed in a matrix on the substrate of the electro-optical unit.

According to the invention, the electro-optical substance may be liquid crystal disposed between the substrate of the electro-optical unit and a counter substrate to achieve a liquid crystal unit.

According to the invention, the electro-optical substance may be an organic electroluminescent substance that constitutes light emitting elements on the substrate of the electro-optical unit to achieve an EL display panel.

The electro-optical unit according to the invention may be used for display units of electronic apparatuses, such as mobile computers and mobile telephones.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described with reference to the accompanying drawings, wherein like numerals reference like elements, and wherein:

FIGS. 1(A), 1(B), and 1(C) are a plan view illustrating the relevant portion of the structure of a semiconductor device according to a first embodiment of the present invention, a sectional view along line IA-IA' in FIG. 1(A), and a sectional view along line IB-IB' in FIG. 1(A), respectively;



FIGS. 2(A), 2(B), and 2(C) are a plan view illustrating the relevant portion of the structure of a semiconductor device according to a second embodiment of the present invention, a sectional view along line IIA–IIA' in FIG. 2(A), and a sectional view along line IIB–IIB' in FIG. 2(A), respectively;

FIG. 3 is a plan view illustrating the structure of the relevant portion of a semiconductor device according to a third embodiment of the present invention;

FIGS. 4(A), 4(B), and 4(C) are a plan view illustrating the relevant portion of the structure of a semiconductor device according to a fourth embodiment of the present invention, a sectional view along line IVA–IVA' in FIG. 4(A), and a sectional view along line IVB–IVB' in FIG. 4(A), respectively;

FIGS. 5(A) and 5(B) are a plan view, viewed from a counter substrate side, of a liquid crystal unit according to the first embodiment of the present invention having components thereon and a sectional view, including the counter substrate, along line H–H' in FIG. 5(A), respectively;

FIG. 6 is a schematic block diagram of a TFT array substrate 10 included in the liquid crystal unit shown in FIG. 5;

FIG. 7 is a view for explaining a data line driving circuit shown in FIG. 6;

FIGS. 8(A), 8(B), and 8(C) are a plan view of wiring lines electrically connected through contact holes in the liquid crystal unit shown in FIG. 5, a sectional view along line VIIIA–VIIIA' in FIG. 8(A), and a sectional view along line VIIIB–VIIIB' in FIG. 8(A), respectively;

FIG. 9 is a diagram of an equivalent circuit of various elements and wiring lines in a plurality of pixels arranged in a matrix to define the image display area shown in FIG. 6;

FIG. 10 is a plan view of the pixels on the TFT array substrate shown in FIG. 9;

FIG. 11 is a sectional view along line A–A' in FIG. 10;

FIG. 12 is a plan view of the driving circuit shown in FIG. 5;

FIG. 13 is a sectional view of a TFT for the driving circuit shown in FIG. 12;

FIG. 14 is an exemplary block diagram of an active matrix electro-optical unit including charge-injection organic thin-film electroluminescent elements;

FIGS. 15(A) and 15(B) are views for explaining a mobile personal computer and a mobile telephone including liquid crystal units according to the present invention, respectively; and

FIGS. 16(A), 16(B), and 16(C) are a plan view illustrating the relevant portion of the structure of a known semiconductor device, a sectional view along line XVIA–XVIA' in FIG. 16(A), and a sectional view along line XVIB–XVIB' in FIG. 16(A), respectively.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Embodiments according to the present invention will now be described with reference to the accompanying drawings.

FIGS. 1(A), 1(B), and 1(C) are a plan view illustrating the relevant portion of the structure of a semiconductor device according to a first embodiment of the present invention, a sectional view along line IA–IA' in FIG. 1(A), and a sectional view along line IB–IB' in FIG. 1(A), respectively.

As shown in FIGS. 1(A), 1(B), and 1(C), a semiconductor device according to this embodiment has a plurality of elements including thin-film transistors and thin-film diodes (not shown) on a substrate 240. Also, the substrate 240 has

the following layers thereon: in order, a first conductive layer 210, an insulating interlayer 220 having a contact hole 221 therein at the position where it overlaps the first conductive layer 210 in plan view, and a second conductive layer 230 electrically connected to the first conductive layer 210 via the contact hole 221. The second conductive layer 230 constitutes second wiring lines extending parallel to an adjacent second conductive layer 250 at a predetermined pitch  $\beta$ , while the first conductive layer 210 constitutes first wiring lines extending orthogonally to the second conductive layers 230 and 250.

In this embodiment, the first conductive layer 210 entirely overlaps the contact hole 221, while the second conductive layer 230 partially overlaps the contact hole 221 in plan view. That is, the second conductive layer 230 is formed at a position shifted with respect to the contact hole 221 in the direction going away from the adjacent second conductive layer 250. Therefore, the contact hole 221 extends beyond an edge of the second conductive layer 230 in plan view, and the first conductive layer 210 is in contact with the second conductive layer 230 at a part of the bottom area 222 of the contact hole 221.

Herein, the contact hole 221 is rectangular in plan view. The second conductive layer 230 partially overlaps the contact hole 221 in its lengthwise direction. Accordingly, the second conductive layer 230 partially overlaps a pair of long opposing edges 226 and 227 of the contact hole 221. On the other hand, the second conductive layer 230 entirely overlaps a short edge 228, which is one of the short edges 228 and 229 of the contact hole 221, namely, the edge further from the adjacent second conductive layer 250, but does not overlap the short edge 229, which is closer to the adjacent second conductive layer 250, at all.

In such a semiconductor device, a distance  $\alpha$  between the adjacent wiring lines in the same layer, namely, the upper second conductive layers 230 and 250, is determined by the design rule defined by the photolithography technology and photolithography machine used. In this embodiment, the width of the second conductive layer 230 can be reduced to be smaller than a width that entirely overlaps the contact hole 221 within the allowed dimensional tolerance. Consequently, a pitch  $\beta$  of the second conductive layers 230 and 250 can be reduced without reducing the design rule distance  $\alpha$  between the second conductive layers 230 and 250.

FIGS. 2(A), 2(B), and 2(C) are a plan view illustrating the structure of the relevant portion of a semiconductor device according to a second embodiment of the present invention, a sectional view along line IIA–IIA' in FIG. 2(A), and a sectional view along line IIB–IIB' in FIG. 2(A), respectively.

As shown in FIGS. 2(A), 2(B), and 2(C), as in the first embodiment, a substrate 240 of a semiconductor device according to this embodiment has the following layers thereon: in order, a first conductive layer 210, an insulating interlayer 220 having a contact hole 221 therein at the position where it overlaps the first conductive layer 210 in plan view, and a second conductive layer 230 electrically connected to the first conductive layer 210 via the contact hole 221. The second conductive layer 230 constitutes second wiring lines extending parallel to an adjacent second conductive layer 250 at a predetermined pitch  $\beta$ , while the first conductive layer 210 constitutes first wiring lines extending orthogonally to the second conductive layers 230 and 250.

In this embodiment, the first conductive layer 210 entirely overlaps the contact hole 221, while the second conductive layer 230 partially overlaps the contact hole 221 in plan view. The second conductive layer 230 overlaps the contact



hole **221** such that two opposing edges of the contact hole **221** are outside of the second conductive layer **230**. Therefore, the contact hole **221** extends beyond both edges of the second conductive layer **230** in plan view, and the first conductive layer **210** is in contact with the second conductive layer **230** at a part of the bottom area **222** of the contact hole **221**.

Herein, the contact hole **221** is rectangular in plan view. The second conductive layer **230** overlaps a center part of the contact hole **221** in its lengthwise direction. Accordingly, the second conductive layer **230** overlaps the center part between a pair of long opposing edges **226** and **227** of the contact hole **221**. On the other hand, the second conductive layer **230** overlaps neither the short edge **228** nor the short edge **229** at all.

In such a semiconductor device, as in the first embodiment, a distance  $\alpha$  between the adjacent wiring lines in the same layer, namely, the upper second conductive layers **230** and **250**, is determined by the design rule defined by the photolithography technology and photolithography machine used. In this embodiment, the width of the second conductive layer **230** can be reduced to be smaller than a width that entirely overlaps the contact hole **221** within the allowed dimensional tolerance. Consequently, a pitch  $\beta$  of the second conductive layers **230** and **250** can be reduced without reducing the design rule distance  $\alpha$  between the second conductive layers **230** and **250**.

FIG. 3 is a plan view illustrating the structure of the relevant portion of a semiconductor device according to a third embodiment of the present invention.

As shown in FIG. 3, as in the first and the second embodiments, a first conductive layer **210** is electrically connected to a second conductive layer **230** via a contact hole **221** in an insulating interlayer **220**. The first conductive layer **210** entirely overlaps the contact hole **221**, while the second conductive layer **230** partially overlaps the contact hole **221** in plan view. Therefore, the contact hole **221** extends beyond an edge of the second conductive layer **230** in plan view, and the first conductive layer **210** is in contact with the second conductive layer **230** at a part of the bottom area **222** of the contact hole **221**.

Herein, the second conductive layer **230** and the second conductive layer **250** extend in parallel at a predetermined spacing therebetween. The first conductive layer **210** extends so as to diagonally cross the second conductive layer **230**. Accordingly, the second conductive layer **230** extends diagonally with respect to all the edges of the contact hole **221**.

In such a semiconductor device, as in the first and the second embodiments, a pitch  $\beta$  of the second conductive layers **230** and **250** can be reduced without reducing the design rule distance  $\alpha$  between the second conductive layers **230** and **250**.

FIGS. 4(A), 4(B), and 4(C) are a plan view illustrating the structure of the relevant portion of a semiconductor device according to a fourth embodiment of the present invention, a sectional view along line IVA-IVA' in FIG. 4(A), and a sectional view along line IVB-VB' in FIG. 4(A), respectively.

In the first, the second, and the third embodiments, the first conductive layer **210** entirely overlaps the contact hole **221**, while the second conductive layer **230** partially overlaps the contact hole **221** in plan view. In this embodiment, the positions may be reversed. That is, as shown in FIGS. 4(A), 4(B), and 4(C), like the first, the second, and the third embodiments, a substrate **240** of a semiconductor device according to this embodiment has the following layers

thereon: in order, a first conductive layer **210**, an insulating interlayer **220** having a contact hole **221** therein at the position where it overlaps the first conductive layer **210** in plan view, and a second conductive layer **230** electrically connected to the first conductive layer **210** via the contact hole **221**.

In contrast with other embodiments, in this embodiment, the second conductive layer **230** entirely overlaps the contact hole **221**, while the first conductive layer **210** partially overlaps the contact hole **221** in plan view. Therefore, the contact hole **221** extends beyond an edge of the first conductive layer **210** in plan view, and the first conductive layer **210** is in contact with the second conductive layer **230** at a part of the bottom area **222** of the contact hole **221**.

In such a semiconductor device, a distance  $\alpha$  between the adjacent wiring lines in the same layer, namely, the lower conductive layers **210** and a lower conductor layer **260**, is also determined by a design rule defined by the photolithography technology and photolithography machine used. In this embodiment, the width of the first conductive layer **210** can be reduced to be smaller than a width that entirely overlaps the contact hole **221** within the allowed dimensional tolerance. Consequently, a pitch  $\beta$  of the first conductive layers **210** and **260** can be reduced without reducing the design rule distance  $\alpha$  between the first conductive layers **210** and **260**.

An example in which the present invention is applied to a liquid crystal unit, which is a typical electro-optical unit, will now be described. In the accompanying drawings, the scales of the layers and the other elements are appropriately altered from the actual ones to enable them to be easily viewed. In the following description, two mutually orthogonal directions on a substrate are referred to as "X direction" and "Y direction", and the extending direction of scanning lines is the X direction and the extending direction of data lines is the Y direction. On the contrary, the extending direction of the scanning lines may be the Y direction and the extending direction of the data lines may be the X direction.

FIGS. 5(A) and 5(B) are a plan view, viewed from a counter substrate side, of a liquid crystal unit having its components thereon and a sectional view of the liquid crystal unit, including a counter substrate, along line H-H' in FIG. 5(A), respectively.

With reference to FIG. 5(A), a TFT array substrate (semiconductor device) **10** of a liquid crystal unit (electro-optical unit) **100** has a seal **107**, as shown by oblique lines that slant to the right in FIG. 5(A), thereon along the edges of a counter substrate **20**. The TFT array substrate **10** and the counter substrate **20** are bonded with the seal **107**, which provides a predetermined gap therebetween. On an outer edge **111** of the TFT array substrate **10**, a data line driving circuit **101** is formed so as to partially overlap the seal **107**. On outer edges **113** and **114** of the TFT array substrate **10**, scanning line driving circuits **104** are formed. In an overhanging area **10c** of the TFT array substrate **10** which extends past the counter substrate **20**, a plurality of terminals **102** are disposed. On an outer edge **112** of the TFT array substrate **10** that opposes the edge **111**, a plurality of wiring lines **105** are formed to connect together the scanning line driving circuits **104**, which are disposed on both sides of an image display area **10a** shown in FIG. 6.

At four corners of the counter substrate **20**, substrate-connecting electrodes **9g** and substrate-connecting components **106** are formed to electrically connect the TFT array substrate **10** and the counter substrate **20**. The number of substrate-connecting electrodes **9g** may be appropriately selected.



In the case where the delay of scanning signals applied to the scanning lines is not a problem, it is apparent that the scanning line driving circuit **104** may be disposed on only one side. In this case, the data line driving circuits **101** may be disposed on both sides of the image display area **10a**.

As shown in FIG. 5(B), the TFT array substrate **10** is bonded to the counter substrate **20** with the seal **107** therebetween, which provides a gap therebetween. The gap holds liquid crystal **50**. The seal **107** is an adhesive to bond the TFT array substrate **10** and the counter substrate **20** together at their peripheries. The seal **107** can be made of light-curable resin or thermosetting resin containing gap spacers, such as glass beads or glass fibers, to maintain a predetermined gap between the substrates.

The TFT array substrate **10** has pixel electrodes **9a** in a matrix thereon, as will be described in greater detail below. On the other hand, the counter substrate **20** has a light shielding film **108** made of a light shielding material, which forms a peripheral partition, inside the seal **107**. The counter substrate **20** has a light shielding film **23**, known as a black matrix or black stripes, thereon at the position opposing the longitudinal and transverse boundaries of the pixel electrodes **9a** on the TFT array substrate **10**. A counter electrode **21** made of an ITO film is formed on the light shielding film **23**.

When this liquid crystal unit **100** is used for projection display units (liquid crystal projectors), three liquid crystal units **100** are used as light valves for the colors R, G, and B. Since light is resolved into colors R, G, and B by a dichroic mirror and light of each color is incident on the corresponding liquid crystal unit **100**, the liquid crystal units **100** do not require color filters. However, when the liquid crystal unit **100** is used for color display units of electronic apparatuses including mobile computers, mobile telephones, and liquid crystal TVs, color filters for R, G, and B, and protective films (not shown) are formed on the counter substrate **20** at the positions opposing the pixel electrodes **9a**, as will be described hereinafter.

FIG. 6 is a schematic block diagram of the TFT array substrate **10** having driving circuits therein for the liquid crystal unit **100**. FIG. 7 is a view for explaining a data line driving circuit **101** formed in the TFT array substrate **10**. FIGS. 8(A), 8(B), and 8(C) are a plan view of wiring lines electrically connected through contact holes in the liquid crystal unit **100**, a sectional view along line VIIIA-VIIIA' in FIG. 8(A), and a sectional view along line VIIIB-VIIIB' in FIG. 8(A), respectively.

As shown in FIG. 6, two mutually orthogonal directions on the TFT array substrate **10** are referred to as the "X direction" and "Y direction", and a plurality of data lines **6a** extend in the Y direction and a plurality of the scanning lines **3a** extend in the X direction. The intersections of the data lines **6a** and the scanning lines **3a** define a plurality of pixels **100a** in a matrix having a predetermined pitch. The matrix of the pixels **100a** defines an active image display area **10a**.

On the outer edge **111** of the TFT array substrate **10**, a plurality of terminals **102** are disposed. The terminals **102** are made from conductive films, such as metal films including aluminum films, metal silicide films, and ITO films. Constant voltages, modulated image signals, and various drive signals are input to the terminals **102**. A plurality of wiring lines **109** made from low-resistance metal films, such as aluminum films, extend from the terminals **102** in order to drive the data line driving circuit **101** and the scanning line driving circuits **104**.

The image display area **10a** has a peripheral area, that is, a flange area **100b** shown in FIG. 5(A). In a region of the

peripheral area next to the TFT array substrate **10** in the Y direction, the data line driving circuit **101** is formed. The data line driving circuit **101** includes shift register circuits **101b**, sample-hold circuits **101c** having analog switches controlled by signals from the shift register circuits **101b**, and six image signal lines **101d** that correspond to respective six phases developed from an image signal.

In the data line driving circuit **101**, the shift register circuits **101b** and the sample-hold circuits **101c** are in one-to-one correspondence with the data lines **6a** and pixel lines connected to the data lines **6a**. That is, with reference to FIG. 7, the sample-hold circuit **101c** is formed for each data line **6a**. In the shift register circuits **101b**, one inverter and two clocked inverters, and one level shifter are formed for each data line **6a**. The one inverter and the two clocked inverters, and the one level shifter define a unit circuit **101e**.

In the TFT array substrate **10**, with reference to FIG. 8(A), the six image signal lines **101d** extend in parallel to one another with a predetermined pitch. Also, a plurality of wiring lines **101f** extend from the sample-hold circuits **101c** in parallel to one another with a predetermined pitch. The wiring lines **101f** and the image signal lines **101d** are electrically connected at their intersections.

To achieve these electrical connections, in this embodiment, with reference to FIGS. 8(B) and 8(C), the first conductive layer **210**, which constitutes the six image signal lines **101d**, and the second conductive layer **230**, which constitutes the wiring lines **101f** from the sample-hold circuits **101c**, can be electrically connected via the contact hole **221** in the insulating interlayer **220**. As described in the first embodiment, the first conductive layer **210** (the image signal line **101d**) is connected to the second conductive layer **230** (the wiring line **101f** from the sample hold circuit **101c**) at a part of the bottom area **222** of the contact hole **221**. Accordingly, the width of the second conductive layer **230** (the wiring line **101f** from the sample-hold circuit **101c**) can be reduced to be smaller than a width that entirely overlaps the contact hole **221** within the allowed dimensional tolerance. Consequently, a pitch  $\beta$  of the second conductive layers **230** (the wiring lines **101f** from the sample-hold circuits **101c**) can be reduced without reducing the design rule distance  $\alpha$  between the second conductive layers **230** (the wiring lines **101f** from the sample-hold circuits **101c**). As a result, the number of pixels can be increased.

FIG. 9 is a diagram of an equivalent circuit of various elements and wiring lines in a plurality of pixels arranged in a matrix to define an image display area **10a** of the liquid crystal unit **100** according to the present invention.

With reference to FIG. 9, in an image display area **10a** of the liquid crystal device **100**, each of a plurality of pixels **100a** arranged in a matrix includes a pixel electrode **9a** and a TFT **30**, which is a switching element that controls the pixel electrode **9a**. Data lines **6a** are electrically connected to the sources of the TFTs **30** to supply pixel signals. The pixel signals **S1, S2, . . . , Sn** are supplied to the data lines **6a** in this order in a line-at-a-time addressing manner. Scanning lines **3a** are electrically connected to the gates of the TFTs **30**. Pulsed scanning signals **G1, G2, . . . , Gm** are applied to the scanning lines **3a** in this order in a line-at-a-time addressing manner at a predetermined timing. The pixel electrodes **9a** are electrically connected to the drains of the TFTs **30**, which write the pixel signals **S1, S2, . . . , Sn** supplied from the data lines **6a** at a predetermined timing by turning on the switching element TFTs **30** for a predetermined period of time. Thus, pixel signals **S1, S2, . . . , Sn**, which have predetermined levels and are written into liquid crystal via the pixel electrodes **9a**, are maintained between



the pixel electrodes **9a** and the counter electrode **21** of the counter substrate **20**, which is described with reference to FIG. **5(B)** above, for a predetermined period of time.

Herein, to the TFT array substrate **10**, to prevent leakage of the maintained pixel signal, an optional storage capacitor **70** can be connected in parallel with a liquid crystal capacitor formed between the pixel electrode **9a** and the counter electrode **21**. The storage capacitor **70** maintains a voltage of the pixel electrode **9a** for a long period of time, for example, three orders of magnitude longer than the source voltage application period. Accordingly, the liquid crystal unit **100** having high contrast display due to improved charge retention characteristics can be achieved. The storage capacitor **70** may be formed either between capacitor lines **3b**, which are wiring lines to form a capacitance, or between the above-described scanning lines **3a**.

FIG. **10** is a plan view of adjacent pixels on a TFT array substrate. FIG. **11** shows a sectional view along line A–A' in FIG. **10** and a sectional view of the TFT array substrate and the counter substrate with liquid crystal therebetween.

As shown in FIG. **10**, the TFT array substrate **10** has the plurality of pixel electrodes **9a** made of transparent Indium Tin Oxide (ITO) films in a matrix thereon. Pixel switching TFTs **30** are connected to each pixel electrode **9a**. The data lines **6a**, the scanning lines **3a**, and the capacitor lines **3b** are formed along the longitudinal and transverse boundaries between the pixel electrodes **9a**. Each TFT **30** is connected to the data line **6a** and the scanning line **3a**. That is, the data line **6a** is electrically connected to a high-concentration source region **1d** of the TFT **30** via a contact hole and a protrusion of the scanning line **3a** defines a gate electrode of the TFT **30**. To achieve the storage capacitor **70**, an extending portion **1f** of a semiconductor film **1a**, which is used for forming the pixel switching TFT **30**, is rendered conductive to form a lower electrode **41** and the capacitor line **3b** overlaps the lower electrode **41** to form an upper electrode.

With reference to FIG. **11**, the base of the TFT array substrate **10** is a transparent substrate **10b**. A bedding protective film **11** made from an insulating silicon oxide film having a thickness of between 300 nm and 500 nm is formed on a surface of the transparent substrate **10b**. A semiconductor film **1a** is formed on the bedding protective film **11** into an island having a thickness of between 30 nm and 100 nm. Then, a gate insulating film **2** made from a silicon oxide film having a thickness of between about 50 nm and 150 nm is formed on a surface of the semiconductor film **1a**, followed by the scanning line **3a** having a thickness of between 300 nm and 800 nm thereon. Part of the area of the semiconductor film **1a** that opposes the scanning lines **3a** with the gate insulating film **2** therebetween is a channel region **1a'**. A source region of a low-concentration source region **1b** and a high-concentration source region **1d** is formed on one side of the channel region **1a'**, while a drain region consisting of a low-concentration drain region **1c** and a high-concentration drain region **1e** is formed on the other side of the channel region **1a'**.

An insulating interlayer **4** made from a silicon oxide film having a thickness of between 300 nm and 800 nm is formed on a surface of the pixel switching TFT **30**, followed by an insulating interlayer **5** made from a silicon nitride film having a thickness of between 100 nm and 300 nm thereon. A data line **6a** having a thickness of between 300 nm and 800 nm is formed on a surface of the insulating interlayer **4**. The data line **6a** is electrically connected to the high-concentration source region **1d** through a contact hole in the insulating interlayer **4**. A drain electrode **6b** is formed on the insulating interlayer **4** simultaneously with the data line **6a**. The drain

electrode **6b** is electrically connected to the high-concentration drain region **1e** through a contact hole in the insulating interlayer **4**.

On top of the insulating interlayer **5**, irregularity forming layers **13a** made of transmissive, photosensitive resin are formed in a predetermined pattern. An upper insulating film **7a** made of transmissive, photosensitive resin is formed over the irregularity forming layers **13a**, followed by a light reflecting film **8a** made of aluminum thereon. Therefore, the surface of the light reflecting film **8a** has an irregular surface pattern **8g** following the irregularities of the irregularity forming layers **13a**. The irregular surface pattern **8g** is shaped like a smooth curve. Although FIG. **10** illustrates hexagonal irregularity forming layers **13a** in plan view, the shapes may be circular, octagonal, or various other shapes.

The pixel electrodes **9a** are formed on the light reflecting film **8a**. The pixel electrodes **9a** may be directly layered on the surface of the light reflecting film **8a**. The pixel electrode **9a** is electrically connected to the drain electrode **6b** through a contact hole in the upper insulating film **7a**, the irregularity forming layer **13a**, and the insulating interlayer **5**.

The light reflecting film **8a** has a rectangular light-transmitting window **8d** at a part of the contact area with the pixel electrode **9a**. Inside the light-transmitting window **8d**, the pixel electrode **9a** made of ITO exists, but not the light reflecting film **8a**.

An alignment layer **12** made of polyimide is formed over the pixel electrode **9a**. The alignment layer **12** is a polyimide film processed by rubbing.

The capacitor line **3b** (an upper electrode) is disposed above the extending portion **1f** (a lower electrode) of the high-concentration drain region **1e** with an insulating film (a dielectric film), which is formed simultaneously with the gate insulating film **2**, disposed therebetween to define the storage capacitor **70**.

Thus, in the liquid crystal unit **100** according to this embodiment, since the light reflecting film **8a** is disposed under the transparent pixel electrode **9a**, light incident from the counter substrate **20** side is reflected on the TFT array substrate **10** side and an image is displayed by the light emitted from the TFT array substrate **10** side (a reflective mode). Light from a backlight unit mounted on the back surface of the TFT array substrate **10** (not shown) to the light-transmitting window **8d**, where the light reflecting film **8a** does not exist, passes therethrough onto the counter substrate **20**, thereby allowing a transmissive display mode as well.

Preferably, the TFT **30** has the above-described LDD structure, however, it may have the offset structure in which regions corresponding to the low-concentration source region **1b** and the low-concentration drain region **1c** are not implanted with impurity ions. Additionally, the TFT **30** may be a self-aligned TFT in which the gate electrode (a part of the scanning line **3a**) serves as a mask to self-align high-concentration impurity ions implanted to form high-concentration source and drain regions.

Although the TFT **30** according to this embodiment has a single gate structure in which a single gate electrode (scanning line **3a**) is disposed in the source and drain region, two or more gate electrodes may be disposed. In this case, the same signal is applied to all the gate electrodes. The TFT **30** having dual (double) or more than three gates prevents leakage current from the contact area between the channel and the source/drain region, thereby reducing the current during an off-state. If at least one of the gate electrodes has



the LDD structure or the offset structure, the off-state current is further reduced, thus achieving a more stable switching element.

In addition to the regions described with reference to FIG. 8, electrical connections using contact holes in an insulating interlayer are employed between the source region *1d* and the data line *6a* of the TFT **30**, between the drain region *1e* and the drain electrode *6b*, and between the drain electrode *6b* and the pixel electrode *9a*. Accordingly, the present invention can be applied to these electrical connections.

The counter substrate **20** has the light shielding films **23**, referred to as "a black matrix" or "black stripes", thereon at the position opposing the longitudinal and transverse boundaries of the pixel electrodes *9a* on the TFT array substrate **10**. A counter electrode **21** made of an ITO film is formed over the light shielding films **23**. An alignment layer **22** made of polyimide is formed over the counter electrode **21**. The alignment layer **22** is a polyimide film processed by rubbing.

With reference again to FIG. 5(A), in the liquid crystal unit **100** according to this embodiment, peripheral circuits, such as the data line driving circuit **101** and the scanning line driving circuits **104**, are formed in the peripheral region of the image display area *10a* on the TFT array substrate **10**. The data line driving circuit **101** and the scanning line driving circuits **104** are basically composed of N-channel TFTs and P-channel TFTs shown in FIGS. **12** and **13**.

FIG. **12** is a plan view of the TFT which constitutes peripheral circuits including the scanning line driving circuits **104** and the data line driving circuit **101**. FIG. **13** is a sectional view of the TFT along line B-B' in FIG. **12**. As shown in FIGS. **12** and **13**, the TFT which constitutes the peripheral circuit can be a complementary-type TFT composed of a P-channel TFT **180** and an N-channel TFT **190**. Semiconductor films **160** which constitute the TFT **180** and the TFT **190** for the driving circuits are formed into islands on the bedding protective film **11** of the transparent substrate *10b*. The dashed line in FIG. **12** shows the outlines of the semiconductor films **160**.

In the TFT **180** and the TFT **190**, a high potential line **171** and a low potential line **172** are electrically connected to source regions of the semiconductor films **160** via contact holes **163** and **164**, respectively. An input wiring line **166** is electrically connected to a common gate electrode **165**. An output wiring line **167** is electrically connected to drain regions of the semiconductor films **160** via contact holes **168** and **169**.

Such a peripheral circuit region can be formed by the same processes as those for forming the image display area *10a*. Accordingly, the peripheral circuit region also has the insulating interlayers **4** and **5**, and the gate insulating film **2** therein. Like the pixel switching TFT **30**, the TFTs **180** and **190** for driving circuits have the LDD structure. A source region consisting of a high-concentration source region **182** and a low-concentration source region **183** and a drain region consisting of a high-concentration drain region **184** and a low-concentration drain region **185** are respectively disposed on both sides of channel regions **181**. Also, a source region consisting of a high-concentration source region **192** and a low-concentration source region **193** and a drain region consisting of a high-concentration drain region **194** and a low-concentration drain region **195** are respectively disposed on both sides of a channel region **191**.

Thus, in the driving circuits, the high potential line **171** and the low potential line **172** are electrically connected to the source regions via contact holes. Also, the output wiring line **167** is electrically connected to the drain regions via

contact holes. Accordingly, the present invention may be applied to these electrical connections.

In the above-described embodiments, the present invention is applied to a TFT array substrate included in an active matrix electro-optical unit as a semiconductor device. However, it should be understood that the present invention may be applied to a device substrate (semiconductor device) included in an active matrix electro-optical unit using thin-film diode elements as pixel switching elements.

Additionally, the invention may be applied to an electro-optical unit using an electro-optical substance other than liquid crystal, for example, a TFT array substrate used for an organic electroluminescent display unit, as will be described hereinafter with reference to FIG. **14**, or fabrication of a semiconductor device other than an electro-optical unit.

FIG. **14** is an exemplary block diagram of an active matrix electro-optical unit including a charge-injection organic thin-film electroluminescent element. With reference to FIG. **14**, an electro-optical unit (semiconductor device) **100p** is an active matrix display unit in which TFTs drive light emitting elements, such as electroluminescent (EL) elements or light-emitting diodes (LEDs) which emit light by flowing drive currents in organic semiconductor films. Light emitting elements used for such an electro-optical unit are self-luminous so that a backlight is advantageously eliminated and the viewing angle dependency is reduced.

In the electro-optical unit **100p**, a plurality of scanning lines **3p**, a plurality of data lines **6p** extending in the direction crossing the scanning lines **3p**, a plurality of common power supply lines **23p** extending in parallel to the data lines **6p**, and pixel regions **15p** defined by the intersections of the data lines **6p** and the scanning lines **3p** are disposed on a TFT array substrate **10p**. The data lines **6p** are connected to the data line driving circuit **101p**, which has a shift register, a level shifter, a video line, and an analog switch. The scanning lines **3p** are connected to a scanning line driving circuit **104p**, which has a shift register and a level shifter.

Each pixel region **15p** includes a first TFT (semiconductor element) **31p** in which a scanning signal is supplied to its gate electrode via the scanning line **3p**, a holding capacitor (thin-film capacitor element) **33p** which holds an image signal supplied from the data line **6p** via the first TFT **31p**, a second TFT (semiconductor element) **32p** in which the image signal held by the holding capacitor **33p** is supplied to its gate electrode, and a light emitting element **40p** to which a drive current flows from the common power supply line **23p** when connecting to the common power supply lines **23p** via the second TFT **32p**. In the light emitting element **40p**, a hole-injecting layer, an organic semiconductor film, which is an organic electroluminescent layer, and a counter electrode made from a metal film, such as aluminum containing lithium, or calcium, are layered on a pixel electrode, although none are shown.

In such an electro-optical unit, since a plurality of the data lines **6p** extend from the data line driving circuit **101p** with a predetermined pitch and a plurality of the scanning lines **3p** extend from the scanning line driving circuits **104p** with a predetermined pitch, electrical connections via contact holes are employed. Accordingly, the present invention may be applied to these electrical connections.

An electro-optical unit according to the present invention, such as the liquid crystal unit **100**, can be used for electronic apparatuses as display units thereof. Examples will now be described with reference to FIGS. **15(A)** and **15(B)**.

FIG. **15(A)** shows a mobile personal computer, which is an embodiment of an electronic apparatus according to the



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present invention. A personal computer **80** includes a main body **82** having a keyboard **81** and a liquid crystal display unit **83**. The liquid crystal display unit **83** includes the above-described liquid crystal unit **100**.

FIG. 15(B) shows a mobile telephone, which is another embodiment of the electronic apparatuses according to the present invention. The mobile telephone **90** has a plurality of operation buttons **91** and a display unit including the above-described liquid crystal unit **100**.

While the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, preferred embodiments of the invention as set forth herein are intended to be illustrative, not limiting. There are changes that may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A semiconductor device, comprising:

a first conductive layer formed on a substrate;  
an insulating interlayer positioned over the first conductive layer, the insulating interlayer having a contact hole, going through the insulating interlayer, that is at least partially disposed directly on the first conductive layer; and

a second conductive layer formed on the insulating interlayer, the second conductive layer being electrically coupled to the first conductive layer through the contact hole;

the contact hole extending beyond either an edge of the first conductive layer or an edge of the second conductive layer in plan view;

the first conductive layer entirely overlapping the contact hole and the second conductive layer partially overlapping the contact hole in plan view; and

one of the first conductive layer and the second conductive layer extending parallel to one another at a predetermined pitch.

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2. The semiconductor device according to claim 1, one of the first and second conductive layers intersecting the other of the first and second conductive layers.

3. The semiconductor device according to one of claim 1, the second conductive layer overlapping the contact hole that is shifted to one side of the second conductive layer.

4. The semiconductor device according to claim 1, the second conductive layer overlapping the contact hole, two opposing edges of the contact hole being outside of the second conductive layer.

5. The semiconductor device according to claim 1, the contact hole being rectangular, but not square, in plan view and the second conductive layer partially overlapping the contact hole in a lengthwise direction.

6. The semiconductor device according to claim 1, the contact hole being rectangular, but not square, in plan view and the second conductive layer extending diagonally with respect to edges of the contact hole.

7. An electro-optical unit comprising a substrate, the semiconductor device according to claim 1 being used for the substrate of the electro-optical unit to hold an electro-optical substance and pixels having pixel switching transistors, and pixel electrodes being disposed in a matrix on the substrate of the electro-optical unit.

8. The electro-optical unit according to claim 7, the electro-optical substance being liquid crystal disposed between the substrate of the electro-optical unit and a counter substrate.

9. The electro-optical unit according to claim 7, the electro-optical substance being an organic electroluminescent substance that constitutes light emitting elements on the substrate of the electro-optical unit.

10. An electronic apparatus comprising the electro-optical unit according to claim 7.

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